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RYERSON STEEL-SERVICE

Spot-welding of aluminum alloy sheet has been intensively studied by the aircraft industry, to develop a better and cheaper joint than can be made by riveting. Here is a complete analysis of micrographs of acceptable welds in 24 S-T, both as welded and after heat treatment

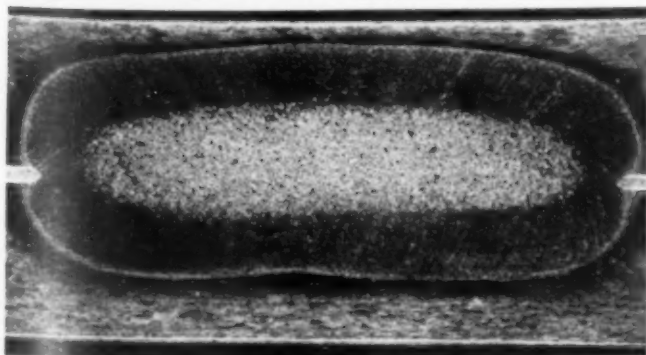
Metallurgical Aspects of Spot-Welds in Aluminum Alloys

IN ORDER TO IMPROVE the spot-welding process it is essential to know what goes on inside the weld, how it is affected by the various external factors of spot-welding, and why these factors affect the strength and other properties of the weld as they do.

Study of the weld structure under the microscope, and application of existing metallurgical knowledge to what is observed, affords information on the basis of which true advances can be made. Investigation of the value of heat treatment in improving the physical properties of spot-welds is also greatly facilitated by metallurgical study.

Published literature on the metallurgy of aluminum alloy spot-welds has been lacking, with the exception of a few papers such as No. 1, 2, 9 and 11 listed in the bibliography (page 1034). These are valuable aids, but do not give the detailed analysis which is now believed desirable.

Fig. 1 — Typical Spot-Weld in Two 24 S-T Alclad Sheets, 0.064 In. Thick. Sectioned, etched with Keller's reagent, and magnified 15 diameters



Examination of Welds (Not Heat Treated)

Microscopic examination of spot-welds made by magnetic stored energy machines in 24S-T alclad sheet reveals four main and distinct zones, as shown in the typical photograph (Fig. 1). The

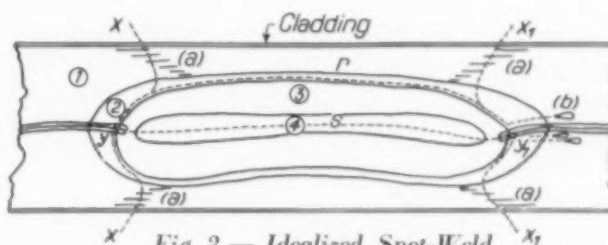


Fig. 2 — Idealized Spot-Weld in Alclad, Sectioned, Showing Principal Zones. Dotted lines indicate course of three modes of rupture

following covers the identification and interpretation of the various metallurgical structures present in these zones; the numbers correspond to the zone designations shown in Fig. 2:

Unaffected Zone (No. 1) — 24S-T alloy, when heat treated and aged, should contain copper aluminide (CuAl_2) particles of a size unresolvable by the microscope, finely dispersed throughout grains of solid solution³.

By J. R. Heising and E. H. Burkart
Research Engineers
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Fig. 3 (above) — Typical Microstructure of 24S-T; Representative of Unaffected Zone, No. 1 of Fig. 2. (Micros are etched with Keller's reagent and magnified 200 diameters, unless it is otherwise noted)

Fig. 4 (center) — Outer Border of Heat Affected Zone, No. 2 of Fig. 2

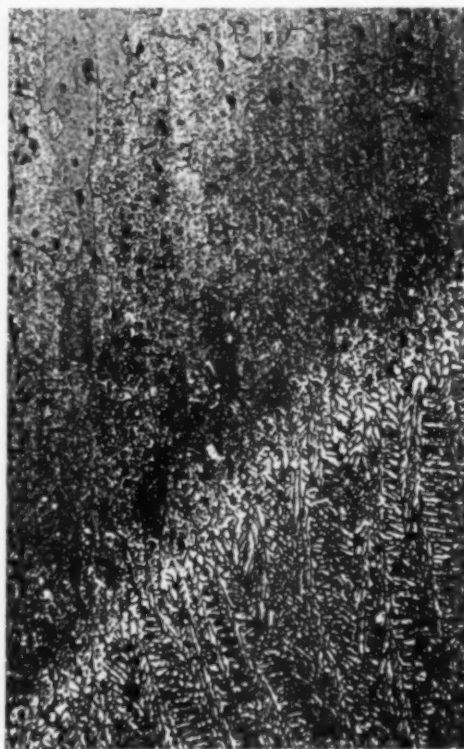
Fig. 5 (below, right) — Heat Affected Zone, Inner Portion of No. 2 of Fig. 2, Showing "Burned" Grain Boundaries. 300X. Rounded dark areas are pits locating crystals of CuAl_2

(Sometimes particles of CuAl_2 , undissolved by heat treatment, are large enough to be visible under comparatively high magnification.) In addition, the alloy will contain numerous dark appearing particles of Al-Cu-Mg and the complex Al-Cu-Fe-Mn constituent, quite characteristic of 24S alloy (Fig. 3). Also, it is suggested that other complex and unidentified constituents formed from aluminum, copper, magnesium and manganese, together with impurities always present, are to be found. Consequently, in the aged conditions the 24S-T alloy will consist of grains of solid solution of copper and magnesium in aluminum

(plus the soluble portion of other elements) together with some metallic and non-metallic inclusions of the kinds described above.

Special Conditions in Otherwise Unaffected Zones—As indicated, in Fig. 2, there are some special conditions under which intrusions will be made into the otherwise unaffected area, the chief of which are "stringers", "filled cracks", and "corona". These are briefly described below.

After spot-welding one may often observe "stringers", noted

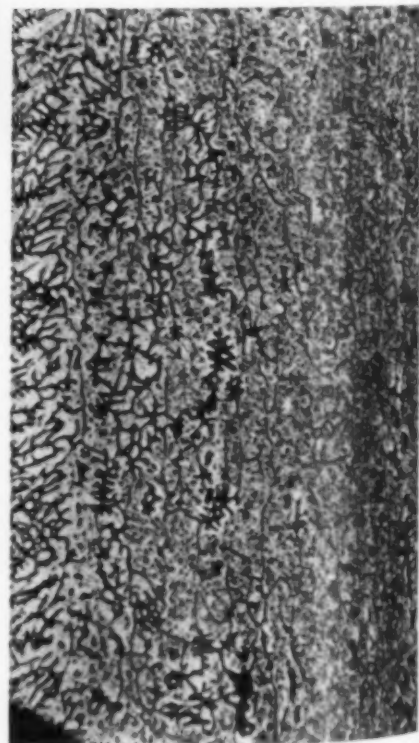


at (a) in Fig. 2. These pass through the otherwise unaffected zone and are caused by the heat generated by contact resistance between electrode tips and sheet surfaces. It is believed that these "stringers" are located around the outer portion of the tip contact area, because of the higher contact resistance and also poorer heat conduction in this zone of lower pressure. This will be mentioned again under "Modes of Failure".

In all spot-welds examined, small longitudinal "cracks" have

been noted in the unaffected zone immediately adjacent to the weld periphery. These are noted at (b) in Fig. 2, and photographed at the right end of Fig. 17, page 1034. These "cracks" (evidently typical of spot-welds in 24S-T alloy) were examined, and it was determined that they were filled with a copper-rich constituent, probably approaching the aluminum-copper eutectic in composition. (It is admitted that this constituent is undoubtedly much more complex than the above mentioned binary one, but for simplicity subsequent discussion will deal with the two-element mixture, as the aluminum and copper content will be the greatest portion of the material and will comprise the major part of the eutectic.) Further discussion of these cracks will be given in the section entitled "So-Called Eutectic Filled Cracks".

A certain amount of fusion of the alclad coating of the two sheets may occur in the region just outside the weld, and is commonly referred to as "corona". Fusion in this area may or may not be complete, but some strength is gained from this effect.



**Fig. 6 to 9 — Dendritic Structures
in Melted Core of Spot-Weld**

Heat-Affected Zone—Upon heating 24S-T material, CuAl_2 tends to agglomerate into larger particles as the temperature increases, finally becoming visible under the microscope. (See photomicrographs, Fig. 4 and 5; the CuAl_2 constituent appears dark because of the etching pits surrounding each particle.)

The inner portion of Zone No. 2 in Fig. 2 shows what appears to be "eutectic" melting along grain boundaries (Fig. 5). Available information on the constitutional or phase diagram for this quaternary Mn alloy (4.4% Cu, 1.5% Mg, small amounts of Mn and Si) is not very explicit. The authors believe that the "eutectic" is formed between a solid solution and CuAl_2 . A recent excellent paper by Keller and Bossert¹⁰ mentions the formation of the "eutectic" upon overheating of 24S alloy, but does not specify the composition of the eutectic. It is of interest to note that although Mg_2Si compound is insoluble in the solid solution matrix, the presence of even small amounts of magnesium (in an alloy of aluminum and copper) reduces the solubility of copper in aluminum. Thus, the eutectic can be forming over a wider range of copper concentration than would be the case in pure binary alloy. The heterogeneity in composition caused by rapid solidification would also be a contributing factor.

The presence of melted and re-solidified alloy is detrimental to the mechanical properties of the material. At elevated temperatures, as well as at room temperature after cooling, the inner portion of Zone No. 2 of Fig. 2 is believed to be the weakest part of the welded joint. In all subsequent discussion this zone in which incipient fusion has taken place, as shown in Fig. 5, will be referred to as the "burned" zone.

The Weld Proper—The structure of the weld "slug" (in the terminology of welding) is shown in the photomicrographs, Fig. 6, 7, 8, and 9. The cast structure of Zones No. 3 and 4 with their typical dendritic form of crystallization shows that this area has actually melted and that upon cooling re-solidification has produced the expected columnar type of structure at the outer part of the slug with equi-axed grains occupying the center. It is assumed that the *width* of the columnar region is subject to the complex laws of crystallization, dependent upon many factors—including the rate of cooling (temperature gradient), velocity of grain growth (linear), and speed of nuclei formation of this particular alloy.

Certain areas in Zone 4 of Fig. 2 show darker spots (see Fig. 1 and Fig. 7) which might at low magnification easily be mistaken for porosity. It should be stressed that examination of these areas



Fig. 6 — Zone No. 3 of Fig. 2 at 600 Diameters

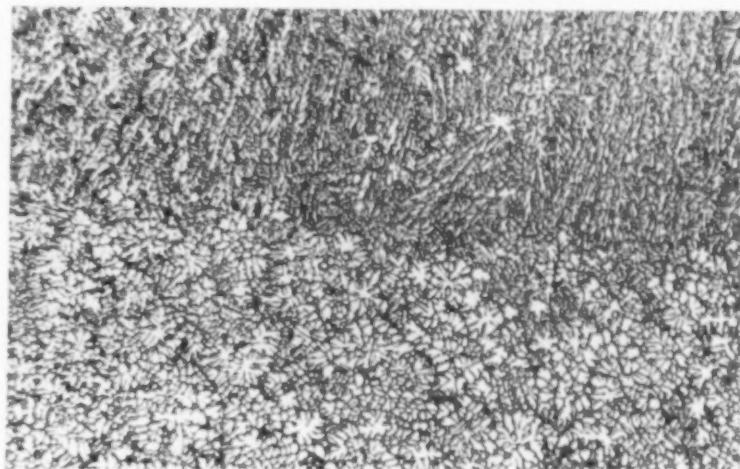


Fig. 7 — Junction of Zone No. 3 and 4 at 200 Diameters



Fig. 8 — Central Equi-Axed Structure of Zone No. 4 of Fig. 2 at 600 Diameters

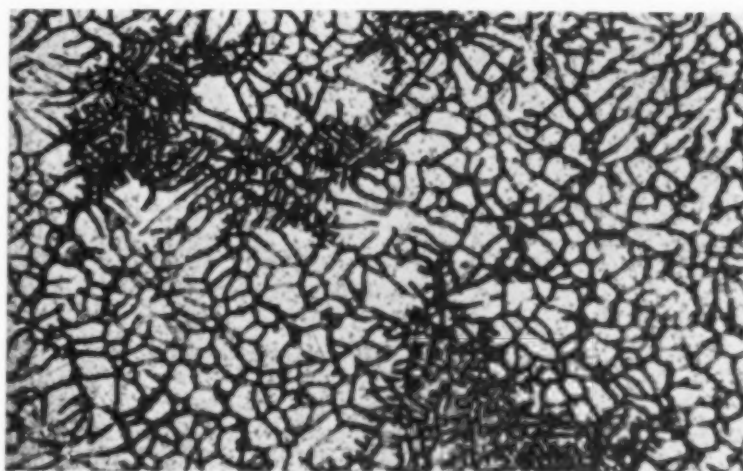


Fig. 9 — Dark Areas in Zone No. 4 Are Clusters of Fine Dendrites, Magnified 600 diameters

at 600 diameters (Fig. 9) shows them to be finer dendrites of the columnar type similar to those in Zone No. 3. These might be caused by localized differences in solidification temperature and rate of solidification, resulting from lack of complete homogeneity in the melt as a consequence of the extremely short time interval (a fraction of a second) available for melting and re-solidification.

All satisfactory spot-welds in 24S-T alloy examined to date showed the presence of all the above zones, but the widths of each varied according to the mechanical and electrical conditions encountered during welding.

So-Called "Cracks", Eutectic Filled—The "cracks", shown at (b) in Fig. 2, and in the right portion of Fig. 17, located in the unaffected Zone No. 1 around the periphery of spot-welds in 24S-T, were examined at high magnification in an attempt

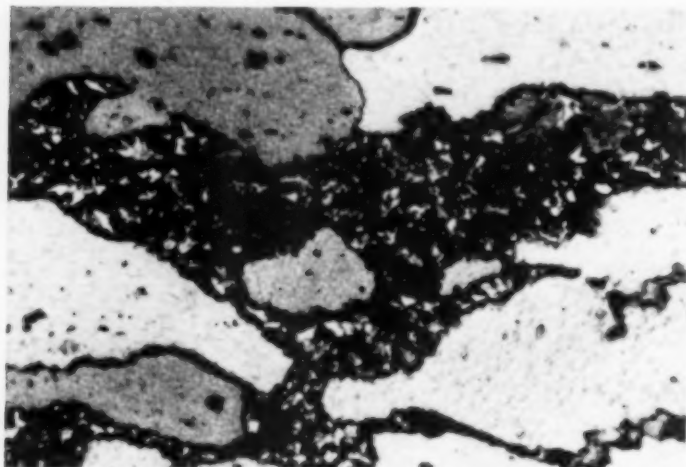


Fig. 10 and 11 — Microstructure, at 1000 Diameters, of Material Contained in "Cracks",

to determine the composition of the filler. Liquid is apparently forced out from the molten slug, by the pressure of the electrode tips, into the molten eutectic-containing grain boundaries in Zone No. 2 which act as conduits. Upon coming to the end of this molten grain boundary zone, and entering the hot border of Zone No. 1, this liquid accumulates due to pressure from behind.

Photomicrograph of Fig. 10 shows one of these "cracks", magnified 1000 diameters, as it appears in the as-welded condition. Keller's etch ($\text{HF-HCl-HNO}_3\text{-H}_2\text{O}$) was used. The filler material has a gray-black structure like a two-phase eutectic, difficult to resolve. Black particles are of some constituent (perhaps Al-Cu-Mg or Al-Cu-Fe-Mn); the white-colored constituent is believed to be the theta or the CuAl_2 phase.

Another "crack" at the same magnification is shown in Fig. 11 which had been given a solution heat treatment following welding—namely, heated to 925° F. for about 25 min. This treatment

rendered the constituents clearly resolvable, because insufficient time at "solution" temperature prevented the appreciable solution of large particles, whereas agglomeration has taken place. (The short interval of time at heat treating temperature prevented any great amount of diffusion of CuAl_2 into the material surrounding the "crack".) The white outlined constituent is CuAl_2 , as proven by selective etching of other specimens. The black constituent is either Al-Cu-Fe-Mn or Mg_2Si , unchanged by heat treatment, or possibly some agglomerated, undissolved particles of Al-Cu-Mg. Gray matrix is aluminum solid solution. Judging from the amount of CuAl_2 (55% Cu) and aluminum solid solution present in the crack, the composition, aside from the Al-Cu-Fe-Mn constituent, approaches that of the Al-Cu eutectic, which would contain less than 33% Cu.

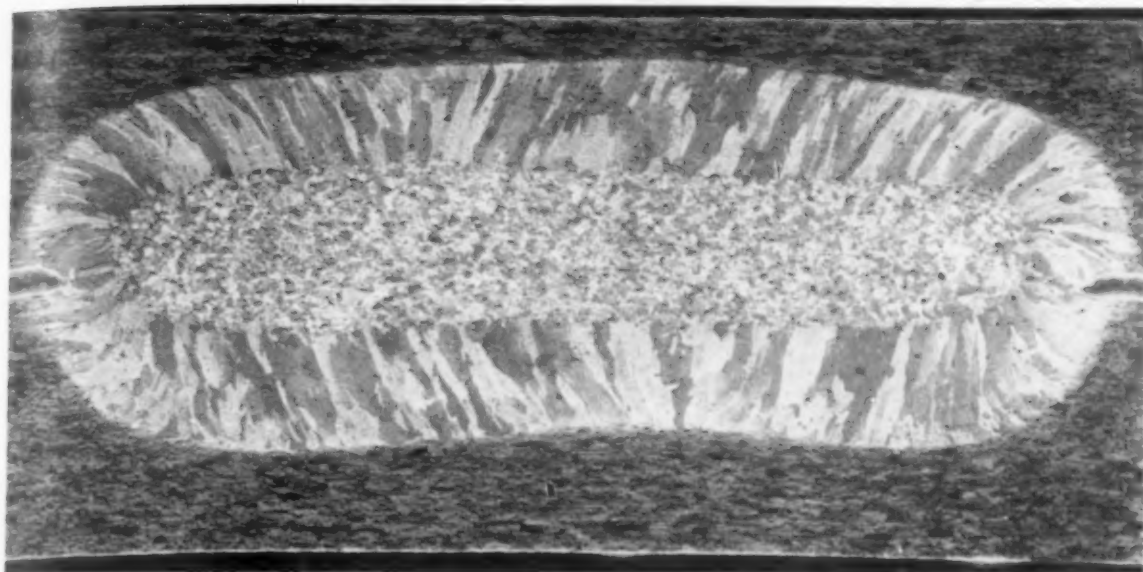


Indicated at b in Fig. 2, Respectively as Welded and After Partial Solution (25 Min. at 925°F.)

Summary of Metallographic Changes

In summary, the metallurgical investigation has shown that the "constitution" typical of heat treated 24S sheet is changed during spot-welding, but that the extent of this change varies due to conditions encountered. The changes are:

1. Actual fusion (melting) has taken place in all welds examined.
2. The weld proper behaves in a manner very similar to that of a cast ingot during cooling.
3. Segregation of some constituents takes place during the welding cycle.
4. Copper-rich liquid is expelled from the weld proper.
5. A gradation in chemical composition is caused by the mode of solidification. This produces the "cored" dendritic segregation typical of alloys when cooled from the molten state. This heterogeneity forms new phases which are not found in the wrought alloy.



Studies of Heat Treated Spot-Welds

24S is one of the alloys of aluminum which will respond to solution and precipitation heat treatment. If we were dealing with the pure aluminum-copper alloy, approximately 4% copper would have been soluble in aluminum at 925° F., whereas at room temperature less than 0.5% copper is soluble under equilibrium conditions. (Of course, the solubility of copper in the complex 24S alloy is somewhat changed by the simultaneous presence of magnesium, manganese, silicon, and impurities.) In the aluminum-copper alloy the precipitation of sub-microscopic particles of CuAl_2 out of this super-saturated solution causes the well-known phenomenon of "aging" and mechanical strengthening of the alloy⁷.

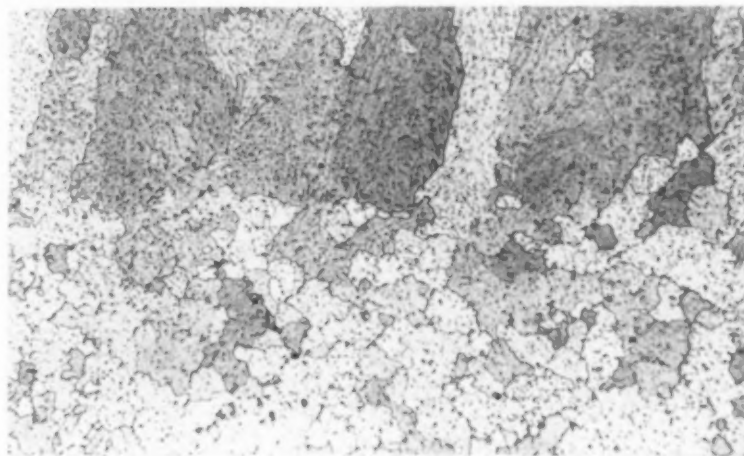
Whether, under the special conditions of solidification and cooling following spot-welding, the CuAl_2 compound is the major constituent coming out of solution in the complex commercial 24S alloy, or whether other constituents, Al-Cu-Mg and Mg_2Si for example, precipitate simultaneously and in what relative amounts, would be a matter of conjecture.

Aging of 24S alloy at room temperature is complete for all practical purposes after approximately 72 hr., and in this condition the alloy is designated as 24S-T. Upon heating 24S-T, the fine



Fig. 12 to 14 — Structure of Welds in 24S-T Alclad After Heat Treatment. Fig. 12 (above) — Entire weld, magnified 25 diameters; Fig. 13 (center) — Junction of zones No. 1 and 2 of Fig. 2, magnified 200 diameters; Fig. 14 (bottom, right) — Junction of zones No. 3 and 4 of Fig. 2, magnified 200 \times .

precipitate of CuAl_2 tends to agglomerate into larger and fewer particles, with a consequent loss of strength together with reduced resistance to corrosion. As already mentioned, this is the condition present in the Zone No. 2 of Fig. 2 which surrounds a spot-weld "slug"; elimination of this zone by re-heat treating the spot-welded material and redissolving this agglomerate



should be of advantage. Also, some improvement should be noted by homogenization of the material through diffusion at heat treatment temperature.

Structural Changes—By actual observation the above prediction was verified. It was found that the following changes occurred through heat treatment of spot-welds in 24S-T material:

Zone No. 1 is unaffected except for slight diffusion of copper and possibly other elements into the alclad coating, the extent of which is dependent upon time at temperature. "Stringers" (indicated at *a* in Fig. 2) redissolved to a great extent.

Zone No. 2—The CuAl_2 agglomerate largely redissolved in the solid solution, and sub-microscopic precipitation later takes place, similar to that following the original heat treatment. "Burned" grain boundaries (incipient fusion) are improved by partial re-solution and homogenization, due to diffusion and solution of CuAl_2 . Thus this major zone of weakness in welds has been greatly improved by heat treating process. Compare Fig. 13 with Fig. 4 and 5.

Zone No. 3—Clearly defined grain boundaries and a partial homogenization of the dendritic "coring" has been effected by solution heat treatment, as shown in the bottom portion of Fig. 14. Complete re-solution and homogenization to remove the cored condition would require a longer time at temperature than that ordinarily given 24S-T alclad sheet.

Zone No. 4—The same general changes have occurred in Zone No. 4 as listed for Zone No. 3. The top portion of Fig. 14 shows traces of the previous "cored" condition in Zone 4.

Corrosion Resistance and Strength—Solution and precipitation heat treatment of these spot-welds improves metallurgically Zones No. 2, 3, and 4 of Fig. 2. However, it promotes slight diffusion of copper from the core into the alclad coating without, it is stated, appreciable damage to corrosion properties.

Holding time at heat treating temperature ordinarily used is insufficient to create a serious problem from diffusion. In fact, U. S. Army Aircraft regulations permit at least one re-heat treatment of 24S-T alclad material. (Slight discoloration of the surface was observed in the spot-welded and heat treated samples.) If carried too far, however, it may tend to reduce resistance to corrosion. Hence, even if it were found expedient to use a relatively long heat treatment (in order to further improve mechanical properties of the welds through more complete homogenization), such procedure would be limited by considerations of corrosion resistance.

Numerous tests revealed an average increase of over 35% in the shear strength of welds resulting from heat treatment. Some results are reproduced in the table.

Improvement in Spot Welds by Heat Treatment

MATERIAL	NUMBER OF TESTS	AVERAGE SHEAR LOAD	MAXIMUM	MINIMUM
As welded, 24S-T alclad	100	1071 lb.	1254 lb.	946 lb.
Heat treated, 24S-T alclad	100	1452 lb.	1618 lb.	1260 lb.
Gain by heat treating		35.5%		

Modes of Failure of Welds

Not Heat Treated—When spot-weld specimens are subject to "pull tests" tending to produce shear in the weld, as indicated in Fig. 15, it should be evident that sheet thickness (stiffness) will have much to do with the resulting stresses and the type of failure produced. Also, the location, shape, and size of the slug may be deciding factors.

It has been determined from examination after failure that spot-welds in 24S-T alclad fail mainly in three different ways shown in Fig. 16.

1. By "pulling the button" (along dotted lines $x-x$, x_1-x_1 , of Fig. 2).

2. Along dotted line $y-r-y_1$ of Fig. 2 ("pull out" shear).

3. Along dotted line $y-s-y_1$ of Fig. 2 ("clean" shear or shear proper).

"Button" type failures are the most common in thin sheet below 0.040-in. gage. The presence of heat-affected "stringers", at points shown at (*a*) in Fig. 2, undoubtedly have an internal notch effect which materially weakens the metal. This condi-

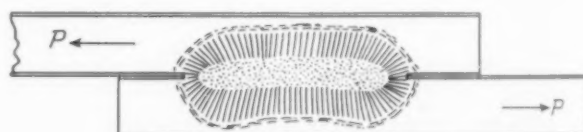


Fig. 15 — Sketch Showing Ordinary Lap Joint Used to Test Strength of Single Spot-Weld

tion and also the lack of sufficient stiffness of the thin sheet to prevent bending under test are the major factors in this type of failure.

"Clean shear", or failure along the plane of the faying surfaces, occurs more frequently in the heavier gages, especially if porosity is present in the central portion of the weld. Small diameter, thick spot-welds may also fail in this manner.

"Pull out" shear is apparently a variation of "clean shear" failure. Such a failure is characterized by the pulling out of a small portion of the weld proper, as shown at center of Fig. 16.

Heat Treated Welds—Solution and precipitation heat treatment of spot-welds in 24S-T will materially improve conditions existing at (*a*) in Fig. 2 and in Zone No. 2. Therefore, if failure

occurs in the original condition along either $x-x_1$ or $y-y_1$, as is normally the case, heat treatment will improve the strength. However, difficulties caused by distortion of parts during heating and quenching will limit its general application to spot-welded joints. There are distinct possibilities of heat treating individual spot-welds, just after they have been made, by a subsequent flow of electric current.

Energy and Heat Conditions in Spot-Welding

The energy dissipated during the making of a resistance weld is given by the expression

$$W = \sum_0^t i^2 r t dt$$

where i is the current (variable in magnitude when welding is done by a transient discharge of stored energy), r is the total resistance from electrode to electrode, and t is time.

Present indications, both theoretical and experimental, are that resistance r resides chiefly in the surface of contact between the two aluminum alloy sheets, since the electrical resistivity of the metal itself is quite low. The oxide film which is present on the surface of aluminum alloy and alclad sheets is of an insulating nature and presents a relatively high resistance, which, when current passes, generates energy for the weld. This oxide is omnipresent, for even after prolonged etching of the surface, a thin film re-forms quickly on exposure to the atmosphere.

Since the thermal conductivity of the sheet material is high, sufficient energy W must be supplied to overcome the rapid heat losses through the sheet and at the electrodes, and still have sufficient surplus to fuse the sheets together. It is possible to calculate how much energy is needed to melt a weld slug of given size in a given time, and determine, taking into account various losses, what the total energy input will have to be.

E. G. Keller and C. B. Jordan, both of Lockheed Aircraft Corp., have made some studies in which experimental data are compared with calculated requirements, and by this process the magnitude of the single unknown variable (the resistance) has been approximately determined. This has corroborated the hypothesis that the total resistance of aluminum alloys is much in excess of that arising from the sheet resistivity alone, hence must be attributed chiefly to the surface contact resistance.

Alternating current spot-welds in 24S-T alloy produce a structure exhibiting annular rings in Zone No. 3 as shown at 12 diameters in Fig. 17. One theory of their formation and cause is as follows: Oscillographic studies⁸ by W. F. Hess and associates at Rensselaer Polytechnic Institute indicate that surface contact resistance, while high

at the outset, has dropped to an extremely low value by the end of the first cycle of welding current input (timing being taken on the basis of equivalent 60-cycle alternating current spot-welding). Also "spot-welds" made at Lockheed in single thick sheets (0.125 in.), using proper machine settings for making two-thickness welds of 0.064-in. sheet, showed no weld slug or cast area when sectioned, polished and etched. This shows that the combination of low body resistance and high heat conduction of the 24S alloy single sheet leaves insufficient heat to melt the alloy.

The above two observations indicate that the alternating current spot-weld slug joining two sheets of 24S-T material must be formed during the initial portion of the current input (an average alternating current spot-weld in 0.064-in. sheet is made with 10 cycles of current) and further current input simply retards the solidification and rate of cooling. Each peak of current, after solidification begins, interferes with and disturbs the columnar grain growth of Zone No. 3 of Fig. 2 by allowing the formation of new crystal nuclei at the retardation peaks. This forms the annular rings in Zone No. 3 shown in Fig. 17, which are actually isothermal envelopes. They accurately determine the rate of solidification and grain growth in the slug under the existing conditions.

It is also possible that similar annular rings might be caused in direct-current spot-welds by

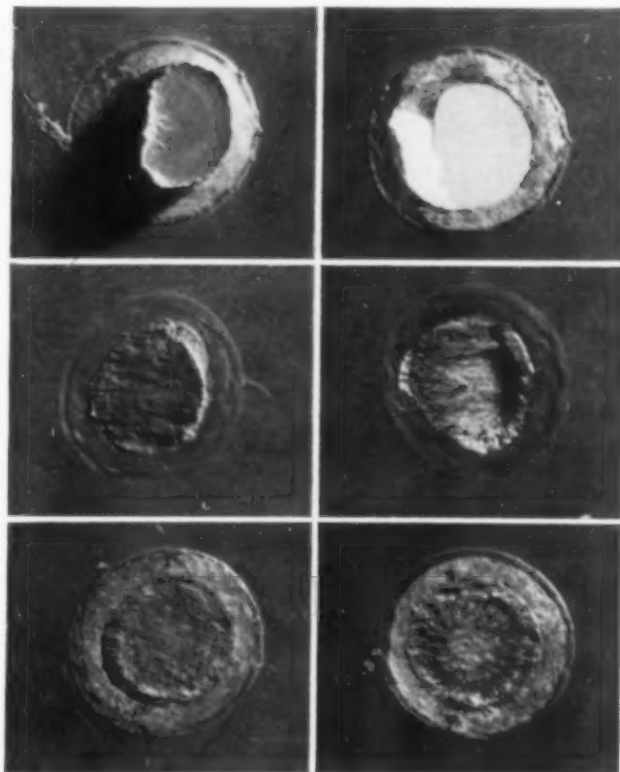


Fig. 16 — Mating Surfaces of Spot-Welds, Enlarged 3 Times, After Pull Tests. Top is "button" type of failure; middle is "pull out" type; bottom is "clean shear"

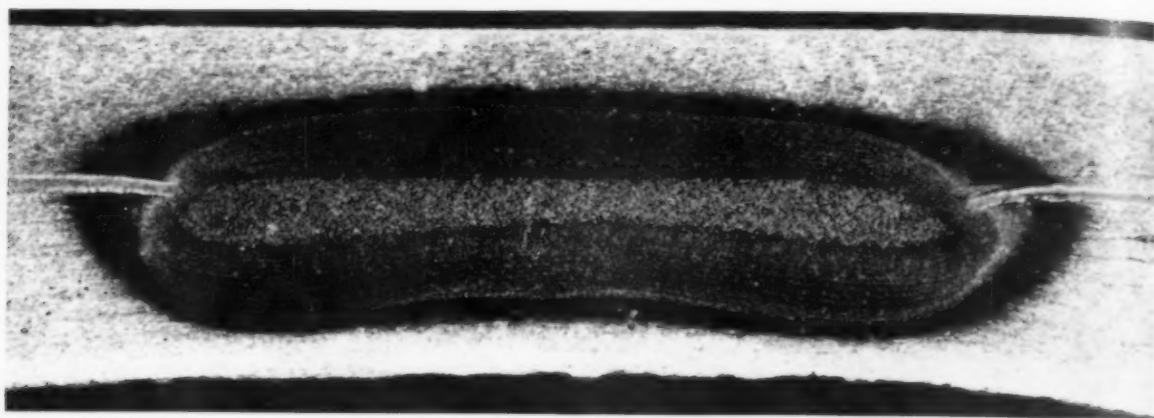


Fig. 17 — Spot-Weld in 24S-T Alclad Sheet Made With Alternating Current. Note "annular rings" in outer zone of slug. Magnified 12 diameters

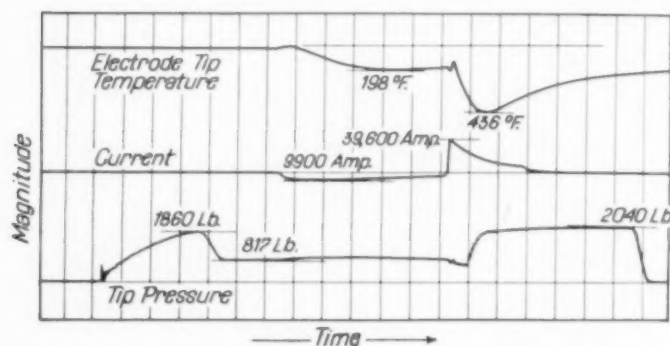
some high frequency mechanical vibration occurring during welding which could also disturb the columnar grain growth. Typical variations in pressure and current in a welding machine which is of the stored energy type are shown in Fig. 18. Electrode tip temperature measurements were made by inserting thermocouples to within $\frac{1}{16}$ in. of the contact surface.

In welding stainless steel and other ferrous alloys the above conditions do not apply, the elec-

trical resistance of the material being high and the thermal conductivity low. Hence, heat is generated by the entire body of the metal and is not readily lost through conduction, and as a consequence the welding of these materials is much less critical than the welding of aluminum alloys. The total resistance, not being so greatly a function of surface contact resistance, is relatively constant for a given alloy, and constant weld quality can be maintained by merely controlling the integrated current input,

$\sum_0^t i^2 dt$. The so-called i^2t controllers work on this principle, but are not applicable to aluminum alloy welding where the variable resistance r is a much more important factor.

Fig. 18 — Representative Oscillograph Record Showing the Variations in Current, Pressure and Temperature of Electrode Tips During a Spot-Welding Cycle in a Machine of the Condenser Energy Storage Type



Future Work

Future work should be so planned as to obtain, if possible, actual correlation of weld structure (in the heat treated and non-heat treated condition) with physical test data and with calculated or measured energy input and heat conditions. A study of the effects of cold work, and of hot forging the weld by recompression, should be undertaken.

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Rapid sorting of alloy steel bars, semi-finished parts, and even scrap, is frequently quite necessary, and while an expert spark tester with his grinding wheel is usually able to do the work, rapid differentiation of the low chromium engineering steels needs a supplementary test

Spot Test for Chromium

THE FOLLOWING METHOD was developed, with the aid of T. R. Henry and R. Knospe in the laboratories of Wisconsin Steel Works, at the urgent request of our spark tester, who has found it very helpful and satisfactory. It is designed for the rapid detection of chromium in bars, billets, or other solid steel sections, and in drillings. It also permits a rough estimate of the amount of chromium present in amounts up to 1.2%.

The method is based on reactions noted in the 1938 edition of Feigl's "Qualitative Analysis With the Aid of Spot Reactions", and differs somewhat from a procedure recommended by Thanheiser and Waterkamp. The latter became known to us, after we had completed our work, through an article in *Archiv für das Eisenhüttenwesen* for Sept. 1941. Although more solutions are required than would be desired for an "ideal" spot test, the equipment may be carried in a small kit and the test can be applied under almost any circumstances. We have not attempted to use it for chromium contents above 1.2%, and the lower limit of detection is about 0.1%. Molybdenum below 0.5% does not seem to interfere seriously. We have not had enough experience with vanadium steels to state with assurance that vanadium does not interfere.

Special Apparatus Required

Porcelain spot plates, size 00 (Coors Porcelain Works, Golden, Colo.)

Set of three reagent bottles with rubber stoppers and dropping pipettes, and two reagent bottles with ground glass stoppers and dropping

pipettes. One of the latter should preferably be of brown glass.

Stirring rods made of 3-mm. glass rod, about 2½ in. long, with ends cut off square and lightly ground.

Clean cloth or paper towels.

Procedure

Solid Steel Surfaces—Prepare a clean, scale-free surface by grinding or filing. Place a drop of dissolving acid (solution No. 2) on the clean surface and allow to stand for about 30 sec., or until violent action ceases. (Do not allow the reaction to continue until the acid is all spent and the drop becomes mushy or dry. The timing should be developed so that the sample is taken from the drop at about the same stage of reaction for each test.) When the violent reaction in the acid drop has about ceased, touch the flat end of a 3-mm. stirring rod to the steel surface under the drop of acid. Remove the stirring rod and transfer the solution which adheres to it to a drop of sodium hypobromite solution (solution No. 1) in one of the depressions of a spot plate. Mix thoroughly with the stirring rod until the flocculent brown precipitate is evenly distributed in the drop. Add one drop of the sulphuric acid solution No. 3, and

By W. O. Philbrook

Research Chemist

Wisconsin Steel Works, International Harvester Co.
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stir until the brown precipitate has dissolved. Add one drop of the phenol solution No. 4, stir slightly, and add one drop of indicator solution No. 5. A faint reddish color will appear if residual chromium is present. The color deepens, with increasing chromium content, through pink to a deep violet color for chromium contents of about 1%. (Color may be compared with that developed in drops from steels of known chromium content; after sufficient experience, it will be possible to identify low, medium, and high chromium contents without the use of comparison standards.) Manganese, copper, nickel, and molybdenum in normal amounts do not interfere.

Drillings — Place one or two small drillings in the depression of a spot plate. Add one drop of dissolving acid. When violent action ceases, remove a small drop with a glass rod and proceed exactly as directed in the section above for solid samples.

Solutions — The spot test may be applied equally well to steel solutions. The solutions to be tested must all contain close to the same weight of steel in a given volume. About 500 mg. of steel per 100 ml. of solution is satisfactory. The steel may be dissolved in sulphuric, hydrochloric or nitric acid, but all iron must be oxidized by boiling with nitric acid before the spot test is made. Then touch the end of a 3-mm. glass rod lightly and carefully to the surface of the solution, so that it just breaks the surface, but does not penetrate to an appreciable depth. The technique of obtaining this small sample must be uniform from test to test. Transfer the solution adhering to the rod to a drop of sodium hypobromite in the spot plate, and proceed with the test as described for solid steel surfaces.

Solutions Required

Solution No. 1: Sodium hypobromite solution. 400 ml. water, 20 g. sodium hydroxide (NaOH), 2.5 ml. bromine (Br₂). *Caution:* Handle liquid bromine only under a well ventilated hood. Avoid any contact of bromine with body tissues. Wear rubber gloves in making up this solution.

Solution No. 2: Dissolving solution. 250 ml. water, 200 ml. concentrated nitric acid (HNO₃), 50 ml. 85% phosphoric acid (H₃PO₄). *Note:* This same solution is used for the nickel spot test.

Solution No. 3: Sulphuric acid (1-5). 25 ml. water, 5 ml. concentrated H₂SO₄.

Solution No. 4: Phenol solution. 5 g. phenol (carbolic acid) crystals (C₆H₅OH), 50 ml. acetic acid (CH₃COOH). Store in glass-stoppered dropping bottle.

Solution No. 5: Diphenyl carbazide indicator solution. Dissolve 0.100 g. of *s*-diphenyl carbazide, [(C₆H₅NHNNH)₂CO] in 5 ml. of acetic acid (CH₃COOH) and dilute to 50 ml. with ethyl alcohol (C₂H₅OH). Store in an amber glass bottle. Replace the solution if it becomes strongly colored.

Notes and Precautions

In any chemical analysis, the final weight, volume, or color intensity used to estimate the quantity of the element in question, depends



Spot Test Equipment Set Out For Laboratory Use, With Four Flasks of Solutions to Be Tested. Small case for carrying reagents in rear

upon the weight of the element in the sample. If colors are to be compared directly to obtain concentrations, then the weights of sample used must be the same.

This general statement is equally true of this spot test. The intensity of color developed depends upon the actual weight of chromium in the small "sample" droplet, even though this weight is exceedingly small. For reproducible results, the weight of steel in the sample droplet must be very nearly the same from test to test. This weight, in turn, depends upon the concentration of steel dissolved in the drop of acid, and upon the volume of the actual "sample" removed from this drop. It may be seen, therefore, that the *time* that the acid is allowed to react with the steel and the *technique* of sam-

pling from the acid drop must be carefully standardized to obtain good results.

It cannot be expected that the same color will be obtained for different methods of sampling — such as sampling from solid surfaces, sampling from drillings, and sampling from solutions — even though the steel has the same chromium content. There are bound to be minor differences in concentration of steel in the acid drop. Comparison standards, or a mental chart of color intensities, must be based upon experience with the actual sampling method used, and it must be maintained uniformly.

The acid dissolving solution will oxidize most of the iron to the ferric condition as it dissolves, during the earlier part of the reaction. As the acid becomes spent, ferric iron is reduced back to the ferrous condition by the steel. All of the iron must be fully oxidized before chromium can be oxidized by the hypobromite solution. If the ferrous iron concentration is too high, there may not be sufficient hypobromite to do the work, and the test will give a false indication. It is important, therefore, to sample from the acid drop before the reaction with the steel has gone too far. A reddish-brown floc should be formed almost immediately when the sample is added to the sodium hypobromite drop. If an extremely heavy precipitate forms, with dark green clots which break up with difficulty, it is necessary to start the test over with a fresh spot of acid, and to change the technique of sampling to avoid such occurrences.

When a number of tests are to be run consecutively, it is convenient to prepare in advance by adding a drop of sodium hypobromite solution to each depression in the spot plate. The acid drops may then be placed on each piece of steel in succession. Sampling and transfer of a droplet from each piece is then followed through in the same order for each consecutive piece. The timing, between placing the drops of acid on the steel pieces, should be about the same as the time for removing the samples and stirring into the hypobromite drop. Be sure to wipe the sampling rod well on a clean towel before each sampling, or use a clean rod for each test.


After the sample has been transferred to the spot plate, the timing for subsequent manipulations is not critical. A few seconds should be allowed for complete reaction by the hypobromite. After the addition of 1-5 sulphuric acid, the precipitate should dissolve completely before any further addition is made. A faint

yellow color should be present in the drop before the phenol is added, otherwise insufficient excess hypobromite was present, and the test should be discarded and started over. The formation of a white cloud or floc after the addition of the phenol does not destroy the utility of the test, although it may alter the color intensity to some extent and make the estimate a little less accurate.

The color develops immediately, upon addition of the indicator. Estimations should be made shortly after the color has been developed, because there is a gradual increase in low colors or fading of deep colors, and a general change in hue upon standing.

Reagents *must* be added in the order directed. The test has been so designed that single drops of the reagents will accomplish the desired result. However, if an extra drop of sodium hypobromite or of 1-5 sulphuric acid should be necessary, or inadvertently added, a single drop of phenol and of indicator should still suffice. Additional drops of phenol or of indicator should cause no trouble. It must be remembered in either case, however, that the volume of liquid in the spot plate is then greater than normal, so the color intensity will appear a little lower than usual for the chromium content present.

By sampling from solutions, as described in the last paragraph under "Procedure", the test can be conveniently combined with other identification tests for nickel, molybdenum, manganese, or a combination. Sampling must be done after oxidation of the steel solution by nitric acid, but before the addition of other reagents.

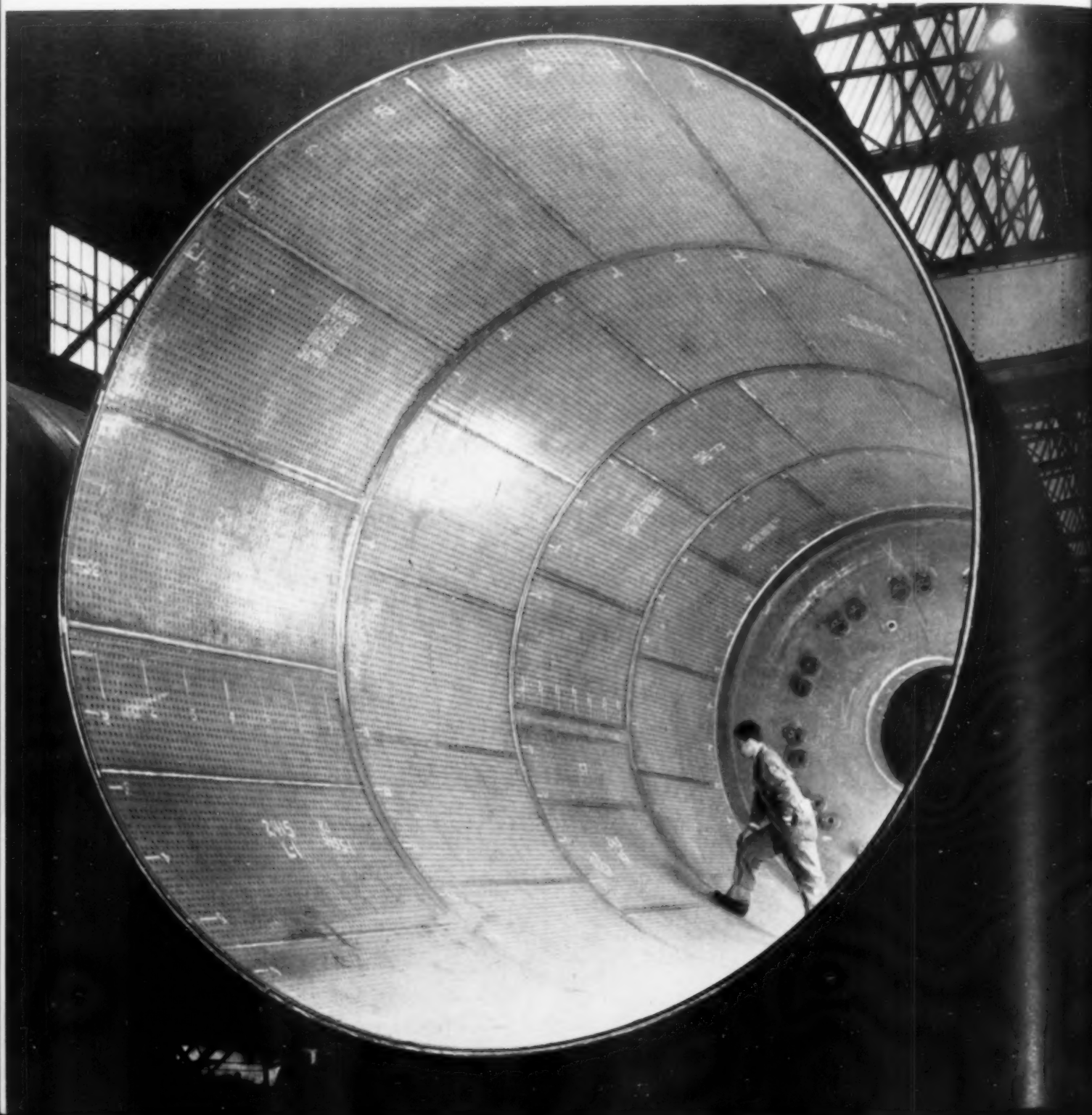
Sodium hypobromite solution No. 1 gradually deteriorates and should be replaced every two weeks or so. Replace the indicator solution once a month. 

Spot Testing in the Mill. Carrying case has reagents for rapid identification of Cr, Ni, Mn and S



A Metallurgical Detail

Pressure Vessel, 12 Ft. Diameter, Under Construction for Chemical Plant; Carbon Steel Shell to Carry the Loads, Stainless Steel Lining to Resist Corrosion. Photo courtesy A. O. Smith Corp.



Lead Being Stockpiled

LEAD is practically unique among metals today for it is the one important metal in which a shortage does not exist at the present time. However, it is impossible to predict what future demands may be, so control must be maintained to assure an adequate supply for any unforeseen requirements. Every effort must be made to keep mine production at peak levels. Our use of lead for all purposes has increased enormously — from 633,000 tons in 1936 to over a million tons in 1941, and we are still using it in very large quantities.

Recovery of secondary lead, a source which yielded 380,000 tons in 1941, must be expected to decrease as the war progresses. The 1942 supply from this source will be only about 90% of 1941, the 1943 supply only about 75% of 1941. Automobile batteries were the main contributor to the scrap pile, but under present circumstances metal from this source is constantly declining, and new metal must be provided in the future to replace that which is not recovered from scrap.

Use of lead in warfare has come a long way from the musket balls of the pioneers. While the most important tonnages are still used in small arms ammunition, a burden on our lead supply undreamed of in former days results from the needs of mechanized war, two-ocean navies, and instantaneous communication. A submarine needs 250,000 lb. of lead for storage batteries alone, and another 200,000 lb. for ballast. This is as much lead as is used in the storage batteries in 8200 automobiles. A signal corps radio, so important in long-range communication, cannot be made without over 100 lb. of lead. The pontoon bridge essential to mobile war needs 82 lb. of lead. Even a motorcycle needs 9 lb. The hundreds of thousands of motorized units and aircraft use lead batteries; electric cable is sheathed in lead; solder and

bearing metals for industrial production are lead alloys; army cantonments and equipment must be protected with lead-pigment paints. High-octane gasoline for aircraft and tanks contains a lead derivative, tetra-ethyl lead.

A normal peacetime year would see many of the same products made, though their end products would be devoted to civilian, rather than military, purposes. The batteries would go into automobiles, the cable into telephone systems, the paint on houses, the tetra-ethyl into gas for autos. A normal year would break down something like this:

Storage batteries	30%
White lead	8
Red lead	8
Buildings	11
Cable covering	14
Ammunition	7
Foil	3
Solder	3
Miscellaneous	16

Several recent developments have contributed to the maintenance of a supply of lead equal to essential demands. The world situation is an important factor.

The United States long has been the world's largest producer (19% of the total in 1938; 23% of the total in 1939); Australia is second with 15%; Mexico produces 13%; Germany plus Austria, 11%; Canada, 10%. In the early days of the war, shipments of lead from America and Australia to Europe were severely curtailed, and much of this metal came into the United States. For example, in 1938 we received no refined lead from Mexico, *(Continued on p. 1124)*

By Erwin Vogelsang
Chief, Tin & Lead Branch
War Production Board
Washington, D. C.

On this problem three viewpoints have recently been strongly expressed: The Truman Committee believes the steel industry has fumbled the development. The Bureau of Mines believes that its experiments presage success. The Steel Industry is skeptical because it has already spent fruitless millions on direct reduction

Is Direct Iron (Sponge Iron) a Substitute for Melting Stock?

SENATOR TRUMAN and his investigating committee have taken trouble to accumulate information on the direct reduction of iron ore without going through any melting stage, and, probably as a result of their report to Congress and the impression that a scrap substitute could be secured in this way from many iron ore deposits not now being worked, and by means less costly in time and money than by the construction of more blast furnaces, a bill was passed early in July appropriating \$600,000 to the U. S. Bureau of Mines to further its investigations of the process. The Editor has written to R. S. Dean, assistant director of the Bureau, for a publishable statement of his view of the process and of the Bureau's plans. In return he sends the adjoining "brief statement prepared for the information of another Government agency". It states clearly the *pro* of this current debate.

Classification of Processes and Their Potentialities

By R. S. Dean

Assistant Director, U. S. Bureau of Mines

RECENT PUBLIC DISCUSSION of sponge iron processes and their possible place in the national economy has led to a degree of confusion regarding the processes and the status of their development.

Iron From Pure Ores

To begin with, we should distinguish three classes of sponge iron. First is iron which is produced from substantially pure iron oxide in the form of mill scale, magnetic concentrates, or exceptionally pure ore, by the use of sulphur-free reducing material such as charcoal, gas or specially selected petroleum coke. Sponge iron of this character has long been an article of commerce and has been produced for many years in Sweden. The Plastic Metals Co. of Johnstown, Pa., has been producing such sponge iron from mill scale and petroleum coke for approximately 18 months. The proposal of the Republic Steel Corp., which has been approved by the War Production Board, to produce 100 tons per day of sponge iron by the gaseous reduction of magnetic concentrates belongs in this category.

These processes, on account of their special requirements of ore and reducing agent, can only produce relatively small tonnages of material for quality uses, such as powder metallurgy and melting stock for electric furnace steel. The Swedish product was formerly imported into this country almost exclusively for use as melting stock for electric furnaces. The Henry Disston Co., of Philadelphia, at one time used 50% Swedish sponge in their steels for saws, even though this material sold at that time for \$42.50 per ton as compared with approximately \$18.00 per ton for good, heavy melting scrap. It is our understanding that the Republic Steel Corp. plans to produce sponge

iron for use as electric furnace melting stock; the procedure will not, therefore, be a general solution of the problem of producing sponge iron as a substitute for scrap in openhearth, or as a means of increasing the capacity of blast furnaces by charging sponge iron in place of part of the ore and coke. The machinery proposed by Republic Steel differs from that which has been successfully used in Sweden or by the Plastic Metals Co., and we have seen no records of pilot plant experiments indicating that the problems of equipment and heat transfer, which are involved in the process, have been solved.¹

Impure Ores Reduced in Kilns

The production of sponge iron from the wide variety of iron ores which are available in this country by means of reducing material, which is also available in quantity, is possible by several methods which have been demonstrated on at least a pilot plant scale in this country or abroad. The problem is to select the processes which can be carried out with a minimum of critical materials and which will use readily available reducing agents.

With the special exception of those areas in this country which possess large resources of natural gas, the only widely applicable processes which can be carried out without new equipment made from critical materials are those processes which utilize rotary kilns. Such kilns are available from the cement and lime industry of the country, an industry which is not operating at capacity. Furthermore, if more kilns are to be built, they require a minimum of new and critical material in the form of carbon steel.

Rotary kiln processes for the production of sponge iron may be divided into two classes. First are those which are carried on below the temperature at which either the iron or the slag melts or agglomerates, and in which the reduced iron is separated from the gangue after cooling by magnetic means. The reduced iron may be pressed into briquettes for charging into the openhearth. Its purity will depend upon the intimacy with which the gangue is mixed with

the iron oxide in the ore and on the sulphur content of the reducing agent. If it is impossible to obtain a sufficiently favorable combination of these factors to produce an acceptable material by magnetic separation alone, the briquettes which are prepared from the magnetic fraction must be heated to a temperature where the impurities form a slag with the unreduced iron oxide; this slag is squeezed from the mass to form a product entirely similar to a wrought iron bloom. By this means a high grade melting stock can be formed from sponge iron made from widely available ores and ordinary coal or coke breeze. This type of sponge iron process has been worked out by the Bureau of Mines over a period of years.² The proper design of rotary kiln for the most efficient reduction of iron ore by solid fuel was described in Bureau of Mines Bulletin No. 270 by C. E. Williams, E. P. Barrett and B. M. Larsen, published in 1927. The procedure of removing the remaining impurities from such sponge iron by heating and squeezing was worked out by the Bureau of Mines in cooperation with the Reading Iron Co. in 1934. The conclusions of the Bureau with regard to kiln design have been confirmed by the Plastic Metals Co. at Johnstown, Pa.

The second type of sponge iron which can be made in a rotary kiln is the so-called Krupp iron.³ In this process, the temperature of the iron after reduction is carried much higher than in the process just described. Furthermore, the constituents of the charge are so adjusted that a sticky slag is formed and the reduced iron is rolled up into the form of nodules or small blooms. This process produces pure iron from low grade ores, using ordinary coal or coke for a reducing agent. This process has been very thoroughly demonstrated in Germany and

²A 27-ft. rotary kiln designed along the lines developed by the Bureau of Mines was operated continuously for 6 months or more in 1923 by Tintic Milling Co. of Silver City, Utah. It produced 2½ tons daily of sponge iron concentrate for precipitating lead and silver from chloride leaches. Charge was fine hematite and coal, fuel was oil, 97% of the iron oxide was reduced.

³As described by Hans Diergarten (letter to *Metal Progress*, May 1935) this mixes the fine, low grade Salzgitter ores with one-third their weight of coal dust, and passes them through a long, rotating kiln of 10-ton per day capacity. Counter current gases dry and preheat the mixture in the upper part; the middle part is externally heated to 1200 to 1900° F. wherein reduction of ore to iron occurs; the discharge end is further heated by internal flame to a temperature where an iron-lime-silicate slag melts, and within which the iron accumulates in semi-porous nodules. Final treatment is crushing and mechanical separation.

EDITOR'S NOTES:

¹An adaptation of the Herreshoff roasting furnace is to be used, a multi-deck furnace very successful for roasting sulphide ores. Prior to the last war experiments were made in the West with similar roasting furnaces charged with mixtures of iron oxide and coal, with the idea of making sponge iron for precipitating copper from leach waters, but the experiments failed either because the required temperatures were too high for the furnace, or because of air infiltration.

Japan, and complete technical descriptions of it are available in the German literature published before the war, and in a number of recent documents which have been picked up by the censor. Both of these processes are ready to go; and, while there are a number of other schemes which will no doubt produce sponge iron, it is difficult to conceive of processes which are simpler and for which equipment and materials are more readily available.

In the special case where natural gas constitutes a plentiful and cheap reducing agent, high purity sponge iron can be made from any ore capable of rigorous concentration before or after reduction. The process of reduction with natural gas was fully demonstrated by the Bureau of Mines and reported in Bureau of Mines Bulletin No. 396, "Sponge Iron Experiments at Mococo", published in 1936.⁴ More recently, the Madaras Steel Co. of Longview, Texas, has erected a plant for reducing high purity sponge iron by natural gas. The Bureau of Mines has arranged to carry through experiments at the Madaras plant in order to confirm its previous work and to determine whether the mechanical arrangements will permit the use of less critical materials in plant construction. (The Bureau has not recommended the commercial utilization of the type of equipment developed in its experiments at Mococo because of the large amount of critical materials involved in building the plant.)

Bureau's Experimental Program

The current experimental program of the Bureau of Mines intends to demonstrate both of the rotary kiln processes described above, using a large number of ores and a wide variety of fuels so that conditions for production in various parts of the country can be established. The Bureau is currently producing from seven to ten tons per day of sponge iron at its Boulder City pilot plant, using a rotary kiln which had been constructed for the reduction of chromite concentrates. The ores which are being reduced at the Boulder City pilot plant are from the deposits available to the Henry Kaiser Co. for use at the Fontana, Cal., steel plant. Fine ore

EDITOR'S NOTES:

⁴Abstracted in *Metal Progress*, June 1938, page 583, and July 1938, page 64. The kinetics of the reduction of magnetite with hydrogen have also been studied and results presented at the Cleveland Meeting (October 1942) of the A.I.M.E. — Technical Publication No. 1509 by M. C. Udy and C. H. Lorig.

from the Provo plant of the Columbia Steel Co. is also being reduced to sponge iron at Boulder City. The further treatment of the product for the preparation of high grade melting stock is being carried out on a sufficiently large scale so that its practicability can be definitely asserted.

The program of the Bureau also encompasses, besides the work at the Madaras Steel Co., mentioned above, the erection of a pilot plant at Laramie, Wyo., in which these rotary kiln processes for sponge iron could be demonstrated on a commercial scale of 50 to 100 tons of iron per day. At the date of writing, construction on this plant is stopped by the order of the War Production Board, but it is regarded as vitally important to make large scale tests of the rotary kiln processes in the near future.⁵

There remains to be mentioned the possibility of producing a relatively low grade sponge iron which could be charged into the blast furnace with a great increase in capacity of such furnace. Such a product can be conveniently made in brick kiln equipment, much of which is now idle. Under extraordinary circumstances, where pure ore and low sulphur fuel were available, the product of this type of operation might also be charged to the openhearth. This process and product are quite similar to that produced in Sweden. The Bureau of Mines is actively cooperating with several brick companies looking toward the revamping of their plants so as to produce sponge iron of this kind.

Our conclusion then is that processes exist for the production of sponge iron from available materials and in available equipment. Detailed engineering features for large scale production need to be worked out; but we feel that a minimum of time and effort should be spent on sponge iron processes requiring new and special equipment and specially purified fuels except where, as in the case of the Republic Steel project, the purpose is to produce relatively small amounts of a high grade product.

⁵On Oct. 22 it was announced that "a committee of individuals with broad, practical, and technical experience is being established by H. G. Batcheller, chief of the Iron and Steel Branch, W.P.B. It will consider ways and means to cope with the shortage of scrap, and advise him on the practicability of individual sponge iron projects which have been submitted to W.P.B." On Nov. 13, Mr. Batcheller wrote to the Editor: "A plant is now being considered by the Bureau of Mines at Laramie, Wyo. At this experimental plant we hope they will be able to solve some of the difficulties which are inherent in most of the processes submitted for the production of sponge iron and will justify us in further consideration of sponge iron development."

The Sponge Iron Process in the Production of Steel

By Advisory Committee on Metals & Minerals

Clyde Williams, Chairman

INTERPOLATION BY THE EDITOR:

A few days after the Congress had appropriated funds for the Bureau of Mines' investigation, the Advisory Committee to WPB on Metals and Minerals (an official group of the National Academy of Sciences and the National Research Council) submitted a requested report on the sponge iron process as it would affect the production of steel. This report is printed in full on the following pages, and is quite unfavorable. It therefore presents the opposite side of the picture painted in Dr. Dean's memorandum.

Perhaps a word of explanation is necessary to harmonize this strong report with the later authorization by WPB of a \$450,000 sponge iron plant to be built by Republic Steel Corp.

H. A. Brassert, well known consulting engineer for the iron and steel industries, and sponsor for the Brassert-Cape low temperature direct reduction process to be installed by Republic Steel Corp., sent to *Metal Progress* a detailed account of the methods and equipment. Unfortunately the censor asked that these details be concealed. It may be said, however, that Republic's attempt is justified by a peculiar combination of circumstances: (a) Fine concentrates from low-phosphorus magnetite ore of exceptional purity, (b) a surplus of coke oven gas suitable for rapid reduction of nine-tenths the oxide, (c) an acute shortage of desirable melting stock for electric furnaces, and (d) electric melting under oxidizing conditions, so that 10% unreduced iron in the charge is not objectionable.

THE MODERN steel making process has gradually evolved from an inefficient, small scale operation, utilizing tiny units, to a highly efficient one utilizing large units almost completely mechanized. The leading position of the United States in the steel industry is due to the possession of easily assembled, high grade raw materials and large scale, highly developed plants. The modern integrated steel operation is largely one of materials handling. The mining and transportation of iron ore, coal and fluxes, coking the coal in by-product ovens, smelting the ore with coke and limestone in blast furnaces, converting the resulting pig iron into steel in the bessemer, or in the openhearth when supplemented with scrap, and fabricating the resulting steel ingots in the shapes of commerce — all are done on a huge scale, mostly by machinery, the majority of the labor being employed either in operating the machine or keeping it in repair.

America Favors Large Production Units

Small unit operations have therefore given way to large ones, those that utilize materials as well as labor inefficiently have been replaced, and at the same time the quality and uniformity of the product have been greatly increased by the development of scientific knowledge and operating skills. Thus, the steel industry in this country is highly developed both mechanically and technically, in which aspects its growth has been as noteworthy as it has in respect to size.

This nation's steel industry, both in size and in technical development, is the peer of them all. It has taken up useful innovations avidly and subjected them to the customary, large scale mechanical development. Examples are the modern blast furnace, which operates with practically no attention and produces 1000 or more tons of iron per day for five years without a shut-down for repairs; the evolution of the electric furnace from its small beginning of 30 years ago to the present highly effective device which will produce 100 tons of the highest quality alloy steel in a few hours; and finally the continuous rolling mills which have replaced the old, laborious hand mills and made possible the huge production rates that are so essential today.

The natural evolution of the steel process in this country was toward the openhearth process which can handle large amounts of steel and iron scrap. Normally, the metallic charge consists of about half pig iron and half scrap. More or less than these amounts, in large variations, may be used; in fact, all-scrap or all-pig iron charges may be used, although it is customary to convert some of the pig iron to steel in the bessemer converter if insufficient scrap is available. Hence, more pig iron is used in times of scrap shortage — that is, in times of high-rate production — and more scrap is used when scrap is plentiful.

Thus it is that the steel industry's use of scrap varies. Today, in order to reach the present large production rates, neither scrap nor pig iron has been available in sufficient amounts, and new blast furnace capacity to produce pig iron has been built and more is under construction.⁶ Pig iron is ideal for conversion to steel. It may be carried molten to the converter and blown to bessemer steel for commercial use, or to a form for use in the openhearth furnace in place of scrap. Pig iron may also be used in higher proportions in the openhearth if additional iron ore of high purity is also charged.



African Natives Make Direct Iron in This Manner

Sponge Iron Proposed as Scrap Substitute

Proponents of the so-called sponge iron process have suggested that to supply the deficiency in scrap, plants be built to make sponge iron rather than pig iron, and claim that sponge iron can be made more cheaply than pig iron, and will serve as a substitute for scrap.

Sponge iron is made by converting finely divided iron ore to the metallic form without melting the ore or the reduced product. It is a sponge-like form of metallic iron, intimately mixed or combined with such impurities, originally present in the ore, as silica, alumina, sulphur and phosphorus. Numerous processes

EDITOR'S NOTES:

⁶Details of the blast furnace program were given in "Critical Points" in *Metal Progress*, July 1942, page 83.

have been developed, but in all of them crushed iron ore is heated to below the fusing temperature out of contact with air, and subjected to reducing conditions that serve to remove the oxygen from the iron. In some processes, pulverized coal is mixed with the ore; in others, a gas (often hydrogen) is passed through the ore.

Sponge iron is not new. In fact, a crude form of reduction process was apparently the first method used by primitive man to reduce iron from its ores, and was a forerunner of the modern blast furnace. Interest in the process, in its numerous variations and its many modifications, has persisted until the present time. The blast furnace process took form in the 14th century, and over some 500 years has been gradually developed as the primary method for getting iron from its ores.

The first recorded definite attempt to make sponge iron was about 100 years ago. Since then, hundreds of methods have been devised and millions of dollars spent in attempting to develop a commercial process. Interest has been intense in this country during the past 30 years, and numerous large corporations have made serious although unsuccessful attempts to make the process practical.

In spite of this century of effort, the process has gained no headway in this country and practically none throughout the world. At Höganäs, Sweden, a process was put in operation in 1909 and has operated more or less continuously since then, producing a few thousand tons yearly. Some of this has been used in the United States for special purposes. In Germany, which lacks coking coal for blast furnaces, the process has been exhaustively studied, but gained no important advancement up to the war. One plant of small capacity is said to be operating at Bochum, but such an operation cannot be said to be economic, or an example for the United States to follow, since here we have an abundance of coking coal cheaply available to every steel producing region.⁷

⁷Possibly also should be included mention of a plant built in 1927 in the north end of the Japanese islands for the reduction of iron beach sand. Partially coked coal (pulverized) was mixed with the sand and rabbled on a flat hearth while being heated from above to about 2000° F. by radiant tubes. Product was concentrated magnetically, briquetted, and melted in electric furnaces, as described by Kotaro Honda in a letter to *Metal Progress*, August 1931, page 89.

Sponge Iron Vs. Pig Iron

Whereas the modern steel making process is adapted to large units, the sponge iron process must be used in small units. A single blast furnace, for example, produces 1000 to 1200 tons of pig iron a day and employs relatively few men for both blast furnace and coke oven operation, while the sponge iron furnaces now under consideration are expected to make only 10 to 20, and certainly not more than 50 tons a day, and would have to employ many times as many men per ton of output. These units are not adapted to automatic operation or to large-scale feeding of raw materials or handling of the product.

The blast furnace has been gradually increased in size and improved mechanically for several hundred years. In recent years, advancement in saving of labor and fuel and in improvement of the product has been particularly marked. As a result, the blast furnace and its auxiliary coke oven plants are models of smooth-running, efficient perfection. The sponge iron process, on the other hand, is still undergoing experimental development. Hence, it is impossible to compare these processes on a cost basis. In view of the fact that nearly the entire cost of pig iron production is represented by the cost of the raw materials and the handling of materials to and from the furnace, one is not justified in assuming that the operating or the plant costs will be less for the sponge iron than the blast furnace process. On the contrary, engineering organizations experienced in the design and construction of iron and steel plants believe that both plant and operating costs will be higher for the sponge iron process than the present process.⁸ History of American

H. A. Brassert estimates that the Brassert-Cape process to be installed by Republic Steel Corp. at Youngstown can produce 1000 tons of melting stock in a department costing \$2,500,000, not including cost of gas producers, ore storage or materials disposal. Undoubtedly this is an optimistic figure, for the War Production Board has approved the financing of a 100-ton plant by Republic Steel Corp. to the tune of \$450,000. The Editor is reliably informed that 1000-ton blast furnaces (without coke ovens or ore bridges) are being built at from \$4,000,000 to \$4,500,000, complete with all the modern improvements.

enterprise has shown that large unit operations are cheaper to build and to operate per unit of output than small unit operations. Hence, one would expect the cost of the sponge iron plant and its overall requirement of construction materials would be greater per ton of output than would a blast furnace plant.

If these cost considerations are neglected and experimental work ultimately results in a sponge iron process workable on a large scale, the product could be used to supplement our scrap supply. Even so, unless the sponge iron were made from ores of exceptionally high purity, the removal of the impurities in the steel making operation would increase the consumption of strategic materials, labor, fuel, refractories, fluxes and ferromanganese enough to make its use decidedly inadvisable. Ores of such high quality are already prized in the present steel making practice. To take them from their present highly strategic use and put them into a product of unproven value would be unwise at a time when every possible pound of steel production is needed. Even if some of the high grade ores were diverted to this use, they would still make a sponge iron product containing 6 to 8% of these impurities and hence

Americans Make Pig Iron With Machinery



having the above-mentioned disadvantages to such a degree as to make this use unwise from the points of view of consumption of critical materials and loss of production.

Moreover, the localities where cheap gas, suitable for reduction of ore to sponge, is available are distant from the high purity ores, with the result that long, expensive freight hauls would be necessary. In Texas, where cheap, natural gas is said to be available, the ores are noted for their high content of impurities. The silica and alumina are high enough to result in a sponge iron so contaminated as to make the use of it in steel melting furnaces extraordinarily costly in rate of output, labor, fuel, fluxes, refractories and ferromanganese. Furthermore, the new steel plant operating in Houston, Texas, is building a modern blast furnace which is expected to be ready to operate in six months whereupon it will supply this plant with its needs. This blast furnace operation will use a poorer grade of ore than is used by any other plant in the United States; coking coal comes from nearby Oklahoma.

Commercial Considerations

1. The sponge iron process is not new. Having been available, basically, since before the adoption of the blast furnace and the open-hearth refining or steel making furnace, and having been before the iron and steel industry in its present form for over 30 years, the fact that this small scale method has not been adopted is evidence of its inferiority compared to present large scale processes.

2. One primary reason for the inferiority of the sponge iron process is that it is not adapted to such large size units as are the present commercial processes. Also, the necessary automatic devices for handling materials, so highly developed and efficient in the present process, are not developed for sponge iron, and are not likely to be developed until after many years of operation. Hence, much more labor to do a given piece of work will be required.

3. The iron blast furnace and coke oven not only handle tremendous tonnages of ore, flux, and coke and use a remarkably small amount of labor, but they require practically no repairs over long periods. For example, a blast furnace will run five or more years without being shut down for repairs. The sponge iron furnace, however, has not been proved to have these advantages because it has never been

operated for a long, continuous period. From experimental results, however, one is justified in assuming that furnace repairs will be very frequent and costly in materials, labor and supervision.

4. Sponge iron would represent a poor substitute for scrap as it is inferior in many respects, a few of which are:

(a) Sponge iron is finely divided and porous in nature and hence, is more readily oxidized in the openhearth furnace. Briquetting to overcome the fineness of division creates an additional operation requiring more labor, materials and equipment. Even the briquetted or highly compressed product is still more readily oxidized than scrap, resulting in loss of iron in the slag and the need for more processing in the steel furnace. This would reduce furnace output and require more labor, more fuel and more ferromanganese and strategic reducing agents.

(b) Sponge iron, even when made from the purest iron ores available and when reduced by hydrogen, contains more impurities, like silica, alumina, sulphur and phosphorus, than steel scrap. This requires the use of additional labor, fuel, fluxes, refractories and ferro-alloys and results in a lower output per furnace. Iron ores pure enough to warrant the use of sponge iron in the steel furnace are not available, for there is an insufficient supply for the present needs of our established steel industry. To take such ores away from the present uses would drastically interfere with production, now geared to the highest rate. And even if this were done, the above disadvantages would exist, although to a lesser degree.

(c) The less pure ores that might be available for the sponge iron process would produce a product high in slag-making constituents requiring excessive use of fluxes, refractories, fuel, labor and ferro-alloys, which would make its use decidedly unwise in present steel melting operations. To build additional melting facilities for this marginal product would be more uneconomic than to build new conventional blast furnace and openhearth or bessemer plants for reasons stated under Paragraph 4-b above.

(d) Unfortunately, the requirements for large amounts of cheap gas and pure ores cannot be met in any one locality. To make use of the large amount of natural gas available in Texas, only the very impure Texas ores could be used. To convert the product into steel or a steel scrap, melting equipment would have to be built. The total materials of construction, time for putting into operation, and labor required for such a development would doubtless be greater than for the conventional process. This is especially true if viewed in the light that the sponge iron process is still experimental and many months of trial operation would

be required before a plant of commercial size could be safely designed and built.

(e) If coal instead of gas is used as a reducing agent, still more slag-making impurities such as silica, alumina and sulphur are introduced, making the sponge iron less suited than ever for conversion to steel. Moreover, coking coals are so plentiful and well distributed in the United States that the advantage claimed for the sponge iron process—that it can use non-coking coals—does not hold. Even in Texas the blast furnace being built in Houston, to make pig iron from Texas iron ores, will use coke made from nearby Oklahoma coking coals.

(f) These observations are true for electric melting furnaces as well as for fuel fired open-hearths. The electric furnace is better adapted to melting sponge iron than the openhearth because its atmosphere is not so oxidizing. Being a more expensive melting unit and requiring electrical equipment and other strategic parts as well as electric energy, such a use should not be considered.

5. Whereas sponge iron, as outlined in Paragraph 4, is less satisfactory than steel scrap as a melting stock for steel production, scrap is less satisfactory than pig iron. Numerous facts attest to this.

(a) The steel industry pays more for pig iron than scrap.

(b) The use of pig iron speeds up the steel making process: It may be added in molten form to the openhearth; it may be converted rapidly to steel in the bessemer; it makes possible the use of iron ore in the openhearth, thus providing steel direct from ore by a simple means less expensive than by way of sponge iron.

(c) It is cheaper to handle pig iron, whether solid or molten, than scrap.

(d) The claim often made that sponge iron, being low in carbon content, is purer and better than pig iron, is contrary to the facts. The slag making impurities in sponge iron are costly to handle and the low carbon content is no asset. The silicon and carbon contained in pig iron enter into the steel making reactions and enable large amounts of iron ore to be used in the charge. For example, by using 50,000,000 tons of pig iron in the openhearth charge, about 4,000,000 tons of additional iron may be obtained from direct reduction of iron ore in the charge. This in itself represents an important method for direct reduction of iron ore, far more efficient and practical than the sponge iron method.

6. From the viewpoint of efficient use of raw materials also, pig iron is superior to sponge iron. The by-product coke oven and the blast furnace both make use of all the raw materials going into them. They produce much

needed by-products. In addition to the coke oven by-products so essential in our chemical industry, the by-product gas is used in the steel plant for melting and for reheating steel for rolling. The "waste" gas from the blast furnace is utilized in making power, melting steel, and in other places requiring fuel. The integrated steel plant needs more gas than it makes as by-product and, hence, wastes none of it.

7. Because no accurate detailed estimates of the cost of commercial sponge iron plants have been made, one is not justified in comparing plant costs of the sponge iron process with the conventional blast furnace process. However, the blast furnace has the expected theoretical advantage of lower cost and lower over-all requirement of construction materials because of its larger scale of operation.

Competent Personnel Lacking

8. Re-examination of the sponge iron process from these angles shows definitely that the process, which has never been operated satisfactorily on a large scale in this country, presents no advantages that would warrant its development at this time. The Government would not be justified in putting money and energy into its development as a war measure. Devotion of time of the nation's production personnel to further attempts to commercialize this process would be wasteful. During the emergency those energies should be devoted to getting the most production of steel products possible by present established methods.

9. The steel making process as practiced in this country is so highly mechanized and efficient and carried on in such large units that the adoption of the small unit, sponge iron process, not possessing mechanical handling equipment and not readily adapted to use it, would be a step backward in our efficient utilization of labor and materials.


10. The undertaking of a program to produce sponge iron to supplement the supply of iron and steel scrap is inadvisable because even though sponge iron would serve as a poor substitute for scrap, it would do so at the expense of labor, furnace capacity, fuel and other essential raw materials. The net result would be a loss rather than a gain in over-all production.

11. If, as a result of a scrap shortage, open-hearth furnaces became idle, then the steel plants would use sponge iron, if it were available, despite its disadvantages. (Cont. on p. 1128)

Bits and Pieces

(Metallurgicus' Own Page)

Temperature Conversions

Mr. TELAUSKAS' easy method of converting Fahrenheit temperatures into closely approximate Centigrade equivalents, and vice versa, (*Metal Progress* for September, page 393) brings notes about an accurate method from Ordnance Inspector JOSEPH G. KOOSMAN and Openhearth Metallurgist FRANK G. NORRIS (thereby winning for them an  book of their choice). Some brains are required, but the minimum. One must remember that the Fahrenheit degree is 5/9 of the Centigrade, and conversely that the Centigrade degree is 9/5 of the Fahrenheit. (If one disremembers this, it can be computed from the interval between freezing and boiling water, 100° C. and 180° F.) To eliminate the confusing 32°, freezing point on the Fahrenheit scale, the procedure in either direction is

1. Add 40 to the temperature
2. Convert
3. Subtract 40 for the *accurate* answer.

Some examples:

Centigrade temperature	60° C.	-40° C.	1600° C.
Add 40	100	0	1640
Multiply by 9/5	180	0	2952
Subtract 40			
(Fahrenheit temp.)	140° F.	-40° F.	2912° F.
Fahrenheit temperature	140° F.	-40° F.	1600° F.
Add 40	180	0	1640
Multiply by 5/9	100	0	911.1
Subtract 40			
(Centigrade temp.)	60° C.	-40° C.	871.1° C.

Case With Controlled Carbon

WE HAVE USED methods and heat treatments somewhat similar to the one outlined in the paragraph of the above title in "Bits and Pieces" in the July issue, wherein the piece is carburized, plated, diffused above A_{c3} , oil quenched, supercooled in dry ice, and tempered. We find

that if the carbon in the case is approximately eutectoid, very little, if any, austenite is retained after oil quenching. Dry ice and alcohol treatment will therefore not increase the hardness. There are good indications that, other details of the heat treatment being the same, the amount of retained austenite in an oil quenched piece is in proportion to the amount of carbon in excess of eutectoid.

We use the dry ice only when the carbon content of the case is high, as frequently occurs when we use a restricted gas flow in the carburizing furnace (thus attempting to produce directly a low carbon case!). We copper plate the part and use the diffusion treatment when the case is designedly hyper-eutectoid. (I. A. USHER, Chief Metallurgist, John Inglis Co., Ltd.)

Memory Aids for Welders

IT TAKES A LONG TIME for a student welder to fix in mind the difference between "straight polarity" and "reverse polarity". (Probably the electrochemical student has the same trouble with "anode" and "cathode".) The usual table

	WORK	ELECTRODE
Straight polarity	+	-
Reverse polarity	-	+

is easy to mix up. Let the student, however, fix his mind on the electrode only; if it is negative (-) the connections are for straight polarity. The mnemonic aid is the connection between straight welding rod, straight sign for negative pole and straight polarity.

A good way to check the polarity on the connections to a direct current welding machine is to take an electrode with organic coating, known to be a reverse polarity electrode, and strike an arc. If there is a loud hiss, high spatter, and little penetration, then straight polarity

exists. (JOSEPH V. KIELB, Welding Engineer, Harrison Radiator Division, General Motors Corp.)

Trouble Shooting for Soft Spots

FOR SEVERAL YEARS a local firm has been making molding dies for plastics by hobbing low carbon steel blanks, pack carburizing, water quenching from the box, tempering in an oil bath, substantially as recommended by DISSTON and DESMOND in *Metal Progress* last April. In mid-July this past summer, trouble was encountered in hardening, the hardened case having soft spots. Examination of carburized and pack cooled pieces showed a case of non-uniform depth, abnormal structure, and mixed grain size, yet no change had been made in material or processing.

Drying the carburizer compound overnight in an oven at 225° F. completely eliminated the trouble. Apparently, the bagged compound had adsorbed enough moisture from the air to interfere with subsequent carburizing operations. This difficulty had never arisen before, but this past summer in this locality was unusually humid. Apparently, there is a maximum humidity (or time of exposure to the humidity) which resulted in excessive adsorption of water by the particular carburizing compound used. All new compound purchased is now being transferred to containers with tight fitting covers. (D. J. MACK, Asst. Prof. of Chemical Engineering, University of Tennessee.)

Temper Without Delay

THE TIME INTERVAL between hardening and tempering is of utmost importance in the heat treating of all the alloy steels, as well as the medium and high carbon (plain carbon) steels. For example, cracking will take place if the medium carbon steels containing about

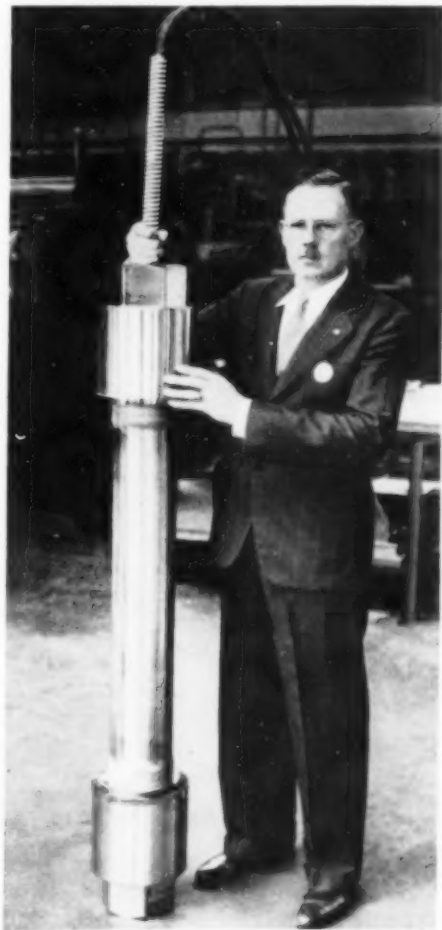
2% manganese are drastically quenched to room temperature and held for some time before tempering. In such steels the stresses develop after, as well as during, the quenching operation. Severe cracking will result when these stresses are allowed to release themselves in cold metal. Tempering immediately after quenching will minimize the stress concentration and prevent damage. However, if the pieces being treated are large enough, the quench may be timed so that there is sufficient heat left in the center of the piece to bring the surface to a temperature above 300° F. This procedure will help to prevent the formation of destructive stresses. (N. C. FICK, Metallurgical Research Division, Gary Works, Carnegie-Illinois Steel Corp.)

Tightening Large Bolts in Place

IT IS COMMON PRACTICE, in important machine assemblies, to tighten bolts and set screws a definite amount by the use of ratchet wrenches or other devices that go out of action when the computed torsional strain has been imposed. In Westinghouse steam turbine construction it is desired to

avoid these torsional strains in large bolts, so they are heated a correct amount, set up snug, and the desired stress imposed as the hot bolt cools.

In practice, the nut is tightened on the cold bolt until it is snug. With the nut snug, the 110-volt electric heater shown in the photograph is inserted in the hole down the axis of the bolt and the current turned on. In about 15 min. a 3-in. diameter bolt is elongated enough for the nut to be given a pre-determined amount of turn. A special micrometer is used to check the stress by measuring the stretch of the bolt; the permissible tolerance on the measured lengthening is -10% to +20%. (ERNEST F. MILLER, Turbine Engineer, Steam Division, Westinghouse Electric & Mfg. Co.)



In Selecting Substitute Steels Watch for "Toughness"

THE PRESENT VOGUE of the Jominy test is warranted as a means of selecting steels to substitute for others of long and satisfactory use but not now available. Minor variations in the hardenability curve may be puzzling yet of little importance; consequently the use of a "hardenability index" is warranted. How this works is as follows: Suppose the part is to have a surface hardness of C-35 in use. Add ten numbers to this (giving C-45 as the quench hardness necessary) and measure the distance from the end of the Jominy test where hardness is C-45. Suppose it to be 10 16 in. Then the "hardenability index for C-45" is that distance, measured in sixteenths of an inch. In symbols

$$J_{45} = 10$$

All steels having hardness of C-45 10 16 in. from the quenched end in the Jominy test are then possible substitutes, each to each.

A word of warning is necessary. Hardenability tests tell nothing about the "toughness" of the new steel when tempered so that the hardness has been let down ten numbers on the Rockwell C scale. Granted that "toughness" means different things to different men, nevertheless it is one quality that resides in the familiar S.A.E. alloy steels that have been long used for more severe duty than could be performed by the plain carbon steels. In general, one would expect, due to the poverty of the NE steels in total alloy, that their "toughness" at equally high working hardness might be deficient. It is a good idea to watch for any tendency toward quench cracking, the first sign of trouble in this respect. (HARRY B. KNOWLTON, Assistant Chief Metallurgist, Tractor Works, International Harvester Co.)

Carburizing Moly High Speed Tools

OF GENERAL INTEREST may be our experience in counteracting "soft surfaces" on hardened molybdenum high speed steel tools which have no grinding allowance. We believed that superficial carburizing would correct such conditions. We also hold that the commercial molybdenum high speeds contain less available carbide than the 18-4-1 steels.

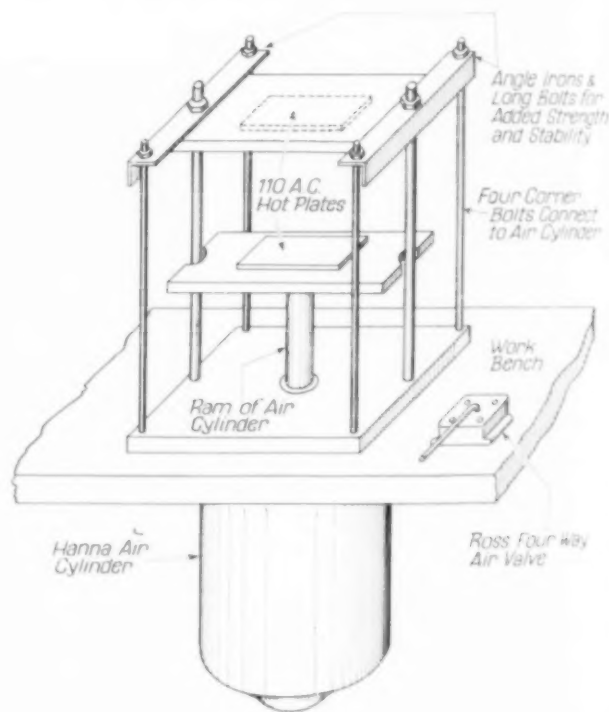
Unfortunately, if too much carbon is added to the surface of a tool, the high carbon austenite formed at the high heat does not transform in the quench, and may even be largely

present after a double draw at 1050° F. This means a file-hard surface but a low Rockwell C-scale reading. The procedure, therefore, becomes rather ticklish, even with the accurate control which gas carburizing allows.

When we occasionally find work with a soft skin, our present practice is to carburize about 0.02 in. deep in 1 hr. at 1700° F. in a Hevi Duty carburizer, then reharden, using a temperature 25° F. lower than the original high heat quenching temperature, followed by the usual draw. We find this procedure more certain of results than pack annealing in cast iron chips. (L. F. TRAIN, John Bertram & Sons Co.)

Trouble-Free Mounting Press

PREVIOUSLY we were using a small hydraulic press for mounting metallographic samples in bakelite. This press, being somewhat antiquated and always in need of washers and fittings, we converted from a hydraulic to an air pressure unit. The plant air line has a pressure of 90 lb. so we bought a suitable air cylinder from the Hanna Engineering Co. (Chicago) and



regulated it with a Ross Four-Way Operating Valve (Detroit). Other simple refinements were added, as can be noted from the sketch. This set-up has given us excellent service for the past three years and has never been in need of repairs. (H. M. SHANNON, Research Department, Phelps Dodge Copper Products Corp.)

"Checks" and "tears" along tensile test pieces are ordinarily indications of hydrogen embrittled spots, known variously as "snow-flakes", "white spots", or "silver streaks". Flakes in forgings, shatter cracks in rail heads, and "pin-holes" near the surface of steel castings, are other manifestations of hydrogen

Defects in Cast and Wrought Steel Caused by Hydrogen

IN A PREVIOUS ARTICLE ON "Fish-Eyes" in Steel Welds" in August *Metal Progress*, the behavior of hydrogen in steel was described simply as an "aging" phenomenon, differing only from well-known aging systems in that the precipitate here is a gas. Slip planes cannot be "keyed" with a gas; consequently, the aging of hydrogen-iron solutions leads to a loss in ductility with no corresponding increase in strength. That phenomenon is a manifestation of *hydrogen embrittlement*.

In that article, a good deal of consideration was paid the shiny areas known as "fish-eyes" in fractured welds because they represent commercially recognized instances of hydrogen aging, or embrittlement. It should be clearly understood, however, that the embrittling mechanism discussed for the fish-eye applies equally to all other defects based upon embrittlement from hydrogen. Even with electroplate, the conception of brittleness from *hydride* for-

mation (or any chemical compound of hydrogen) is a fallacy and should be forgotten.¹

Visible discontinuities in the metal, such as blowholes or inclusions, are of incidental importance, since they serve to localize the hydrogen in a given section and thereby to confer upon the fracture across that section the characteristics that have led to the numerous nomenclature of fish-eyes, snow-flakes, silver streaks, white spots, rosettes, and so on. Otherwise there is no interdependency of embrittlement and those macro-discontinuities. Steel without detectable porosity, when containing enough hydrogen, may suffer general embrittlement, as pictured in Fig. 2 and 3 in the former article — page 203 of the August issue.

In Fig. 10² is an illustration of the harmful effect hydrogen may have on *sound* steel. In this experiment duplicate specimens of sheet were annealed 30 min. at 1750° F., one in hydrogen and one in air. After rapid cooling, and cleaning by sand blasting, each sheet was reduced 50% by cold rolling. The hydrogen-treated sheet tore badly along the edges, because the slip planes in that specimen were congested and immobilized by the precipitated gas. Inter-

¹"Hydrogen embrittlement" in this discussion refers only to brittleness from elemental hydrogen, which is transcrystalline. Hydrogen reaction products cause intergranular embrittlement, as in "copper sickness", or hydrogen attack of the metal in hydrogenation chambers. To speak of "hydrogen embrittlement" of copper is in reality a misnomer, since oxygen is as necessary as hydrogen. In any event, *elemental* hydrogen is implied throughout this discussion unless otherwise noted.

²Illustrations will be numbered consecutively, for ease in reference when the entire series of articles is consulted.

By Carl A. Zappfe
Research Metallurgist
Battelle Memorial Institute, Columbus, Ohio

esting proof, incidentally, for the conception of the behavior of this gas in mosaic disjunctions stands in the two small samples shown in the lower portion of Fig. 10, representing clippings from the two sheets deep etched with hydrochloric acid. Distention and intercommunication of the slip plane disjunctions caused by the hydrogen was so pronounced in the one sample that corrosive liquids were enabled to penetrate that metal to enhance greatly the etching action.

In other manners this destruction of the slip mechanism manifests itself. "Checks" or "tears" frequently develop along the sides of tensile specimens, particularly of weld metal or cast metal. A popular explanation is that a subcutaneous inclusion, which is invariably present, has caused a peculiar concentration of stress during testing, but this explanation is almost eerie. Certainly the more reasonable answer for most cases is that the inclusion has acted as a seat for hydrogen to form a zone of embrittlement that reaches the surface, for complete fracture invariably discloses the white hydrogen fracture, and preliminary annealing usually prevents tearing—obviously without removing the inclusion.

In Fig. 11 (a) is a normal tensile specimen showing "tears", and in Fig. 11 (b) alongside is the specimen from Fig. 6 (page 201, August issue) showing the same kind of marking developed on the thin stripe of hydrogen-embrittled metal artificially produced by electrolysis. Fitted end to end in both Fig. 11 (a) and (b) are the complementing sections of each test piece, the top one photographed after deep-etching. In Fig. 11 (a) of the natural weld specimen, note how the entire zone around the longitudinal line of inclusions has dissolved before the surrounding normal unembrittled metal has scarcely colored; likewise the snow-flakes now look like the eye sockets in a skull.

The artificially embrittled specimen in Fig. 11 (b) contains even more remarkable information, for the etching was not done until fully a year after electrolysis had made that narrow strip brittle, and the test piece had been broken. In that time the embrittlement had certainly disappeared, for room temperature aging requires much less time than one year for so small a hydrogenated region or section. Thus, we may assume that the distention of the slip plane structure is fairly permanent at room temperature and remains even after the embrittling quantities of hydrogen are gone. Only by annealing would normalcy be regained. Furthermore, we may probably presume that, although the hydrogen mechanism carries many similarities to cold deformation, one important difference is that the mosaic blocks are shifted and rotated into keying positions by cold work, but are only partially separated and then "frozen" by embrittling quantities of hydrogen forming a sort of local matrix of highly compressed gas. As a result, after the distending force is reduced by removing a critical quantity of hydrogen, the mosaic structure may retain some inflation without noticeably affecting the strength or ductility, for the blocks are not yet rotated and keyed. Delicate extensometric tests would probably show an uncommon initial increase in density when plastically deforming such material. That embrittlement is coeval with a marked decrease in density is well known.

Shatter Cracks

Of major economic importance is another defect whose basis also is hydrogen embrittle-



Fig. 10 — A Plain Steel Sheet Was Cut in Two; One Half Annealed in Air and the Other Half Annealed in Hydrogen. The first withstood cold rolling and subsequent deep etching; the second's edges cracked on cold rolling and developed mosaic markings on deep etching. Rolled sheets above, two-thirds natural size; pickled samples below at 2 diameters



Fig. 11 (a) — Test Piece Cut From a Heavy Slab of Weld Metal Containing a Longitudinal String of Inclusions Around Which Gathered Embrittling Hydrogen. Lower part, and lower fracture showing "fish-eyes", are in natural condition; upper part of test piece, and upper fracture, have been deeply etched

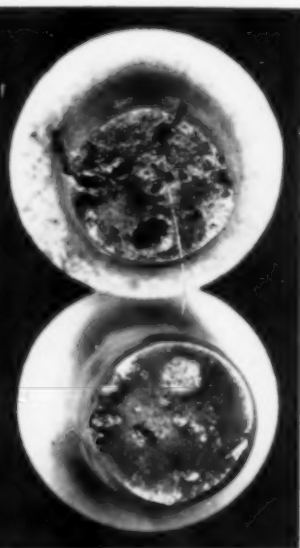


Fig. 11 (b) — Test Piece Which Had Been Artificially Embrittled Along Narrow Strips Made Cathodic During Electrolysis (the Rest of the Specimen Being Protected). Note three fractures starting in lower portion. Upper half was etched a year later; the microstructure of the hydrogenated portion remains disorganized and dissolves readily, even though embrittlement has long vanished



ment, namely the flake or shatter crack in steel forgings—a defect which is still with us and a perennial subject of debate. The specimens just described offer a simple clarification of flakes and shatter cracks. In them the fissure across the embrittled zone was caused by an imposed stress, such as cold deformation from tensile or impact testing. In larger sections

At (b) are corresponding specimens fractured after normalizing, whereby normal metal is made fibrous and the coarsely crystalline fracture of hydrogen-embrittled region surrounding the inclusion becomes pronounced. The micrographs, Fig. 13 (a) and (b), taken at the inclusion seating the embrittlement, show a transcrystalline crack running perpendicularly.

When the steel is infested with them, a horizontal section through a rail head may give good registration of shatter cracks. In Fig. 14 is such a specimen, rolled from a portion of a heat of steel that had been "blown" with hydrogen gas while molten in the ladle, kindly loaned by Prof. R. E. Cramer of the University of Illinois. Figure 15 is another

—and particularly in alloy steels having important volume changes from transformations or precipitations occurring in or near the elastic range—internal readjustments may be predicted having sufficient force to rupture embrittled zones when they are unable to move plastically because of hydrogen. In such cases, exactly the same phenomenon occurs as a "tear" on a tension test piece, but it occurs internally.

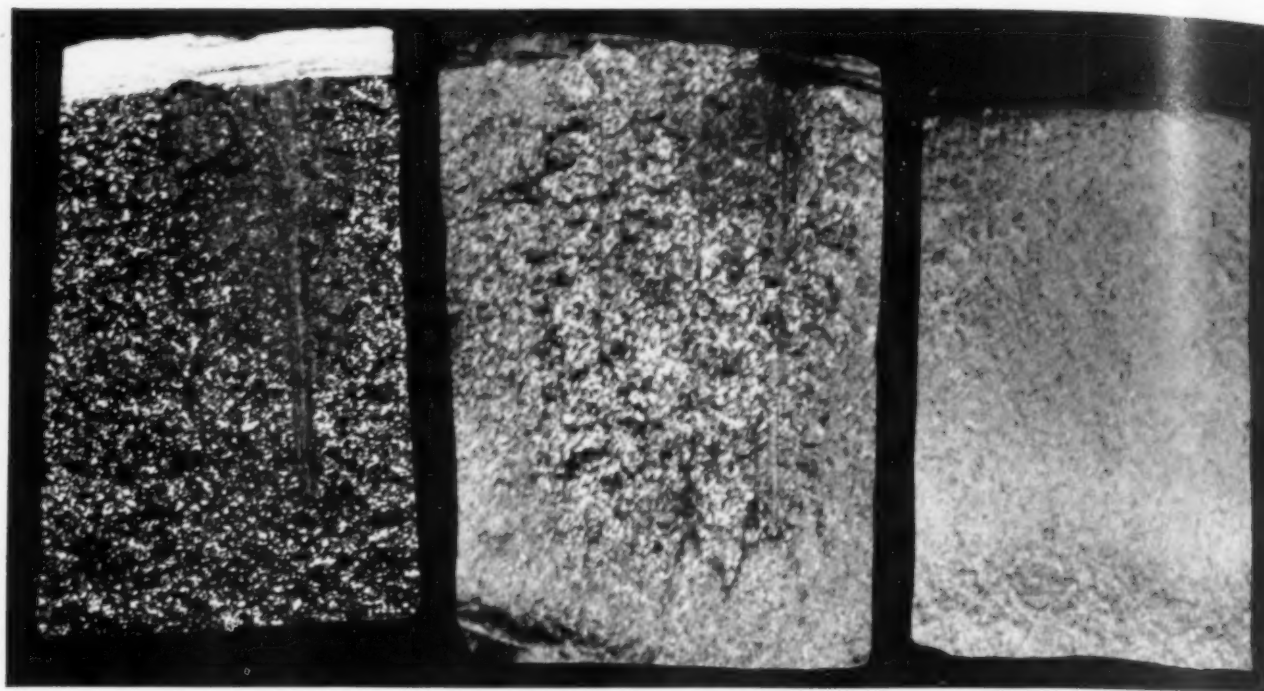


Fig. 12 — Macrographs of Fractured Rail Heads. At left is "feathery" fracture in rail as rolled; at center is similar defect after

rail was normalized to refine grain of surrounding unaffected metal; at right is fractured rail steel having no embrittled zones

specimen of a heavy rail; after rolling it was sound, but it then was annealed in hydrogen for 7 hr. at 2000° F. Masses of shatter cracks occurred and of such a range of sizes that the largest succeeded in nearly splitting the specimen in two pieces.

The photograph in Fig. 16 shows that specimen about double size after subsequent normalizing and breaking with a hammer. The blackened area represents the pre-existent surface of the crack which oxidized during normalizing. Immediately surrounding is the characteristic sheen of hydrogen-embrittled metal, and only at the very surface of the rail has sufficient hydrogen been lost to permit a gray, fibrous fracture.

Transverse fissures in rail have caused fatal and expensive wrecks, since the internal fissures form nuclei for fatigue failure under the incessant pounding of the car wheels and can grow to dangerous size before any surface indication appears. In Fig. 15 and 16 a transverse fissure has actually been developed from internal thermal

stresses alone, because the embrittlement from hydrogen was so severe. There was no ductile metal throughout the section to support the necessary shifting. Defects of that degree are readily detected; the occasional small flaw is the threatening one because it grows undetected.

Hydrogen in Cast Steel

In passing, some other hydrogen-caused defects might be mentioned to show the range of this deleterious element. Steel castings have their share of hydrogen troubles. Just as the gas precipitates in the solid state to congest intra-lattice planes, so will it tend to cause

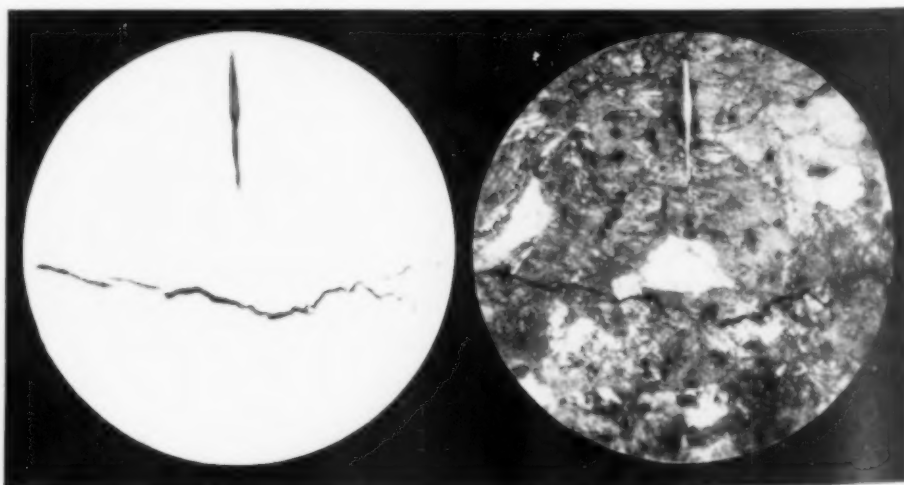


Fig. 13 — Micros, Unetched and Etched (200 X), of Shatter Crack in Rail Steel; It Is Transcrystalline and Perpendicular to Inclusion Seating the Embrittlement

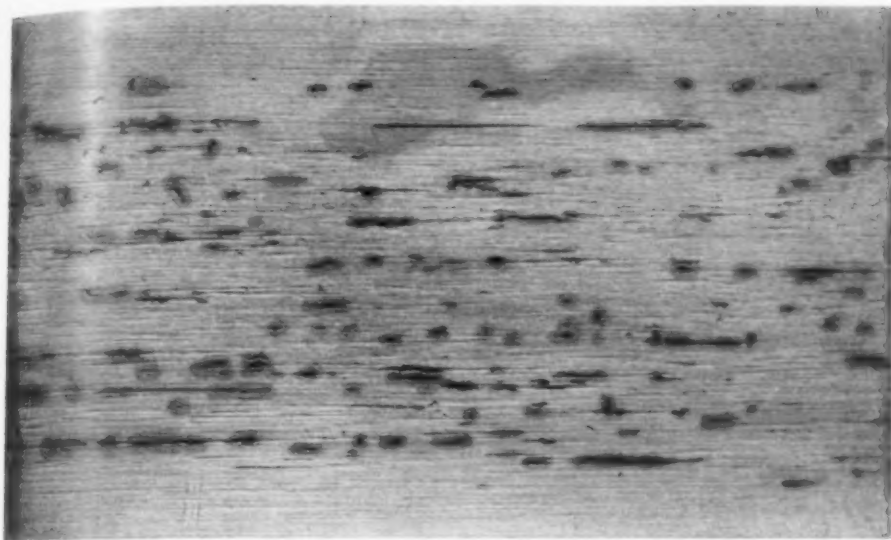
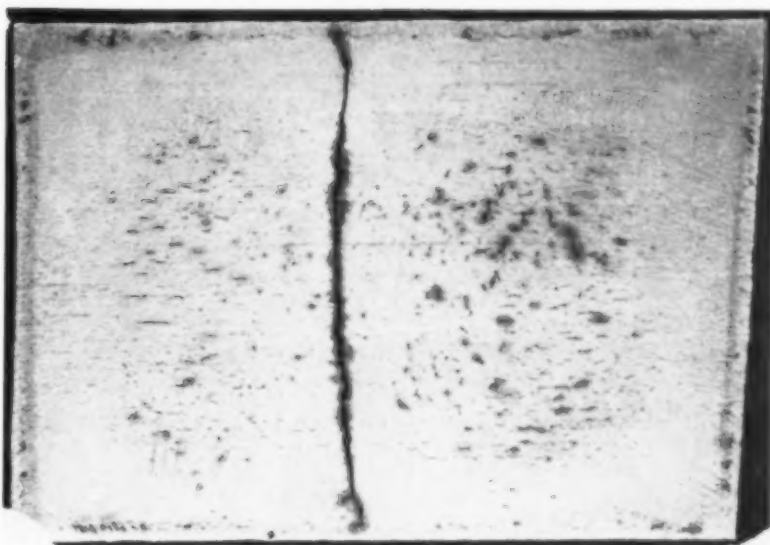


Fig. 14 — Shatter Cracks in Rail Head (Longitudinal Section, Full Size) Made From Steel That Had Been Blown With Hydrogen While Molten. Photo courtesy R. E. Cramer

Fig. 15 (Below)—Originally Sound Rail Head Filled With Shatter Cracks (and in Fact Split Across) Which Formed Upon Cooling From an Anneal in Hydrogen



visible porosity when leaving the iron matrix during solidification. That tendency is strong, as may be noted in the steep solubility curve for hydrogen in liquid steel and the pronounced isothermal change at the solidification temperature (Fig. 1, page 202, *Metal Progress*, August 1942). The "white spot", mentioned by foundrymen, often with a shiny interior denoting the presence of a reducing gas like hydrogen, is the welders' "fish-eye", and results from hydrogen-containing bubbles forming while the metal is still in the mushy stage.

If dendrites form rapidly enough to suppress the bubble formation, hydrogen will behave much as any other impurity during cooling and will diffuse to interdendritic positions to cause voids and perhaps embrittlement. Figure 17 on page 1056 shows a macro-section (full size) through a low alloy steel casting having pronounced interdendritic voids.

The melt had been split. The first half was cast normally and showed mild dendritic structure without porosity; the remaining metal was saturated with hydrogen and resulted in marked dendrites and voids, as shown. The fact that *all* impurities, including hydrogen, diffuse universally to interdendritic positions has caused

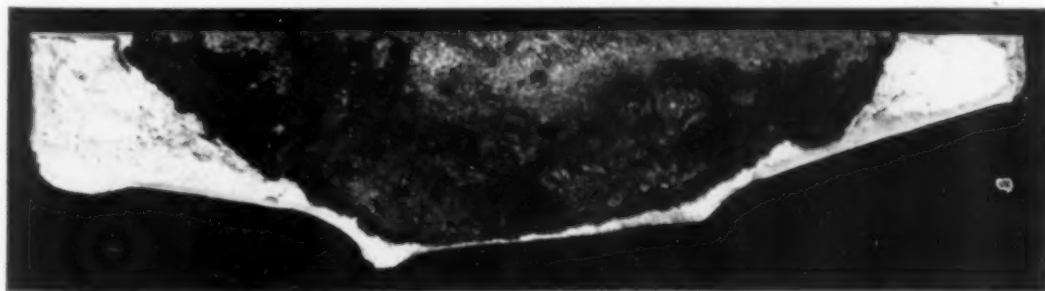


Fig. 16 — Fracture of Fig. 15 (Enlarged to Double Size), Broken After Normalizing. Blackened area represents original crack surface oxidized during normalizing. Note bright surrounding metal, embrittled by hydrogen, and thin skin of ductile steel from which hydrogen has been lost

some investigators to confuse the cause of flakes, for example, with the various other elements sometimes found segregated there.

Mechanism of Pin-Hole Formation

During casting, a subcutaneous type of porosity called "pin-holes" may also develop from hydrogen. In this case, the action definitely involves initiation of the holes by another gas which is apparently water vapor. Hydrogen is a strong deoxidizer and must maintain an equilibrium with oxygen in the steel, much as do other better known deoxidizers. Contact with the moisture in sand molds, and possibly with organic matter in coated molds, will release nascent hydrogen at the surface of the casting, which diffuses into the steel with a facility many times greater than any of the other elements released at the same time. The balance between hydrogen and oxygen is thereby upset within the solidifying skin and insoluble water vapor is formed. The solubility for all the components is so much less in the solid than in the liquid iron that bubbles form at the solid-liquid interface as an excretion from the solidifying wall.

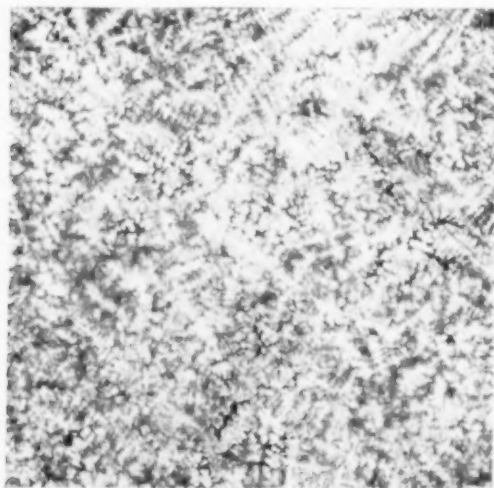


Fig. 17 — Macrostructure of Nickel Steel Casting Showing Interdendritic Porosity Caused by Hydrogen Introduced to the Melt Just Before Casting

Once the bubble is formed by the reaction product, an internal surface is developed which both provides a surface for precipitation of dissolved gases, and demands that they precipitate to an extent that will furnish an extra-lattice partial pressure conforming to the residual solution. The bubble propagates in this manner and grows along the cooling gradient, perpendicular to the wall in most cases, until the

solidifying dendrites overtake the bubble and enclose it. The mechanism is illustrated in Fig. 18.

The reasons for selecting this explanation do not warrant repeating here, but among the salient considerations, for example, is the fact that heavily killed steels do not develop pin-

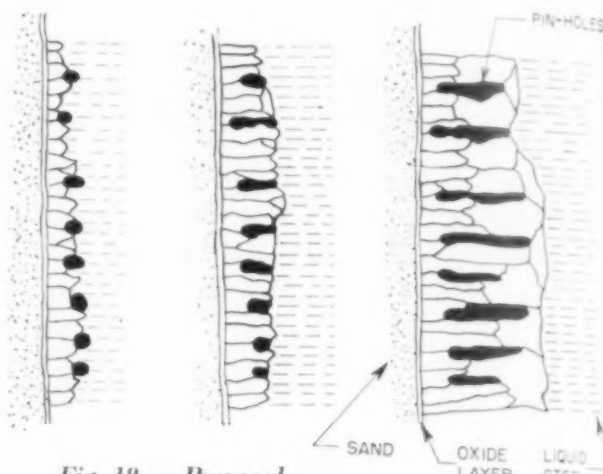


Fig. 18 — Proposed Mechanism for the Formation of "Pin-Holes" Near the Surface of Steel Cast in Sand Molds

holes and yet are often less ductile. Presumably the absence of free oxygen in such steels prevents bubble formation, and the absence of bubbles requires hydrogen later to precipitate within the lattice, causing embrittlement.

A second consideration is the following: Hydrogen is certainly necessary for this particular type of pin-hole porosity, yet saturating the liquid steel with hydrogen does not lead to pin-holes, presumably because the saturating treatment is a deoxidizing treatment. We believe that hydrogen in itself does not cause steel to crack and is not a likely cause in itself of pin-holes. In the one case an imposed stress is necessary, and in the other a gas-producing reaction with another element seems necessary.

A gaseous product, of course, is much more insoluble than its components. One must not forget that the solubility of hydrogen is a function of pressure, as well as temperature; consequently, in forming a bubble, hydrogen would develop the pressure necessary for sending most of the gas back into solution in the liquid adjoining.

This relationship gives a good account for the ubiquitous supersaturation of hydrogen in steel. In the absence of a "boil", for example, about the only way the hydrogen can escape is by diffusing out of the surface.

Critical Points

By the Editor

■ TO PITTSBURGH, to a meeting of the Electric Metal Makers Guild, Inc., a ten-year old group of some 150 melters — melters exclusively — and found their problems to be those common to other branches of the industry, namely, men and raw materials. As outlined by HARRY WALTHER, president of the Guild, these problems are all the more acute because of the recent large expansion of capacity. Tonnage of steel ingots alone is expanded approximately three-fold; 6½ million tons of aircraft quality alloy steel ingots are expected in 1943, plus as much more as will be possible to squeeze out by such expedients as can be arranged after an interchange of information about practices in the most efficient shops.

Melters and melting stock needed for electric steel

....A supply of good help (labor) must be made, for it obviously is not to be found. HENRY BIGGE told me something of the intensive training for up-grading, given in the electric melt-shop to likely and willing men already in Bethlehem's employ. The Guild itself is hoping to organize a specialized course for furnace helpers which can be repeated in various steel centers....Allocation of proper raw material for electric furnace charges is being given close attention by the War Production Board. Since the electric furnace is primarily a melter of selected scrap (being a relatively inefficient refiner for removing carbon, phosphorus and silicon) the necessary millions of tons of plate clippings and low phosphorus structural scrap do not exist. Even now it is sometimes necessary to ship crop ends long distances, from rolling mills serving openhearth, to hungry electric steel plants. The future will undoubtedly extend the use of the openhearth as a preliminary refiner of low grade scrap, serving the electric furnace with hot metal. Also the steel foundry's triplex process has great possibilities: Melt scrap in cupolas, take out much of the sulphur with caustic soda in the ladle, blow out carbon and silicon in a bessemer, dephosphorize in a mixer, and finally refine and alloy the hot metal

in the electric furnace. It is also known that Republic Steel's interesting project to make direct iron by hydrogen reduction of magnetite concentrates is exclusively to provide desirable melting stock for making electric steel.

OFF THE MAIN LINE to Peoria, for the first time, to visit Caterpillar Tractor Co., spread out during the last 25 years over the Illinois prairie into a vast factory for tractors, road machinery, and diesel engines, and now making tractors, tank transmissions and gun mounts. Running through the dozens of interesting operations exhibited by GLEN RIEGEL, chief metallurgist, the numerous uses of induction heat for hardening appear and reappear, and foreshadow the importance of this process to peacetime industry of tomorrow. Caterpillar was the first to install "Tocco's"

Versatile induction hardening process for continuous hardening of cylindrical parts; that was in 1938. Now 14 complete units are scattered throughout the production lines, mostly on pins and shafts, but even for spot hardening rocker arms and small accessories. Also a Budd internal induction hardener (with cam control as complicated as the drum on an antique music box) for the bore of cylinder liners of alloy cast iron. And the largest machine yet built, for final drive gears over 2 ft. in diameter....Since pins are surface hardened, one after another, by pushing them end to end through ring-shaped inductors, plans are under way for hardening and tempering the original bars the same way in mill lengths, prior to machining....Impressed with the conclusion that induction hardening is not alone valuable as a speedy operation, but even greater economies come from using lower alloys in surface-hardened parts, replacing higher alloy steels either carburized or fully hardened. This certainly is an especially valuable feature in recent months when alloy has been scarce or unobtainable. For instance, heavy shafts and draw bar pins for Caterpillar's tractors, formerly of S.A.E. 2345, are now made of plain carbon steel, induction hardened. Small shafts and accessories, formerly of carburized 2320, are now of 1040, induction hardened, and push rods of the same carbon steel instead of X-3140.

ALL THESE CHANGES are very recent; quick and confident modifications of this sort are possible only because the Caterpillar engineering staff has 25 years' experience in appraising steel

by its maximum capabilities in use rather than by its chemical composition. How it works is this: A heat of steel ordered to Caterpillar specifications is rolled to bloom or billet, and samples from first and last ingot are expressed to Peoria for acceptance test. Complete investigation—for chemistry, cleanliness, segregation, soundness, surface, hardenability, normality, tensile properties, notch-bar toughness—is completed in less than 48 hr., and “go-ahead” or “divert” signal given the steel mill within the

**Purchase
properties
rather than
chemistry**

time normally required for pit-cooling a high grade billet, and so this routine does not delay the steel mill. Fifteen years ago, one out of three heats of difficult alloy steel like S.A.E. 2345 might be refused, for it would have given serious trouble in fabrication or use of tractor parts; steel refining practice has so improved that now one bad out of ten good heats might be expected only when a new analysis or furnace practice is being perfected. In 1941 the grand average was 3% of heats diverted.... Naturally individual machine parts have certain properties which are of paramount importance. For instance, track links must have sound, unsegregated centers because critical stresses occur around pin bosses located in the center of the billet; induction hardened, water quenched gears must have critical hardenability limits to avoid root cracking; leaf springs and killed carbon steel channels for main frames must have good Charpy impact values at -40° F. to avoid failure during winter service—all these, of course, in addition to the proper balance of other properties.... An organization grounded in such a metallurgical tradition will have the boldness to convert a $3\frac{1}{2}\%$ nickel steel gear to a plain carbon steel, even though it involves a three-year development program costing \$500,000. Right now, however, this one item is saving 144,000 lb. of scarce nickel every year.... Viewing the metallurgical and financial balance of two decades, GLEN RIEGEL is insistent that buying for intended use (as the Europeans do) is a far better plan than buying a definite analysis (as is standard American commercial practice). Caterpillar Tractor Co. has a laboratory geared up to make rapid tests so steel production is not delayed; likewise its buying power is large enough so the steel mills play ball. To extend this salutary practice would obviously require agreement by numerous important producers and consumers,

for the smaller user with limited metallurgical facilities cannot take advantage of the proven opportunities until *all* the steel mills put more emphasis on definite physical characteristics of their product, ready for shipment, than on chemical analysis and hot working properties. Is this a job for the American Society for Metals, or for the American Society for Testing Materials? It would be better for industry to study the matter promptly than to have some governmental agency issue a regulation.

FOUND A GREMLIN (as a flyer would call it) put to work in the Caterpillar foundry. Tellurium is its name, and “gremlin” or “kobold” or “devil” would be too polite for the old-time western miners to call that element when combined with gold in ores that assayed like a bonanza, yet milled like country rock! The foundrymen do not like it too well, for it gives them a garlic breath, but it’s 1200 times as effective as chromium to chill gray iron. Idle wheels for tractor tracks used to be cast of 0.50% chromium iron; now there is no chromium for alloy iron, so use a

**Tellurium
of use to
a foundry**

pinch of tellurium! Practice is to put a 60-gram (2-oz.) pinch of ferrotellurium in a 2000-lb. bull ladle, and then reladle and pour the molds from hand ladles. Result: A $\frac{3}{4}$ -in. rim of hard white iron on tread and flange.... Wonder how long it would have taken to find the trouble if an odorless kind of tellurium had inadvertently got into cupola iron to the extent of 0.0005% to spoil its machinability. (Now here’s boron too, as a hardener for steel when added in thousandths of a per cent. Bring on your spectrosopes and the periodic sequence!)

Isn’t There Something Wrong Here?

THESE are two adjacent items in “Personal Service” (Help Wanted) in a recent issue of one of our contemporaries, published by an American engineering society:

Metallurgists, young, for laboratory test work on steel and brass. \$3000 — \$3600. Chicago; interviews, East. W-1018 CD.

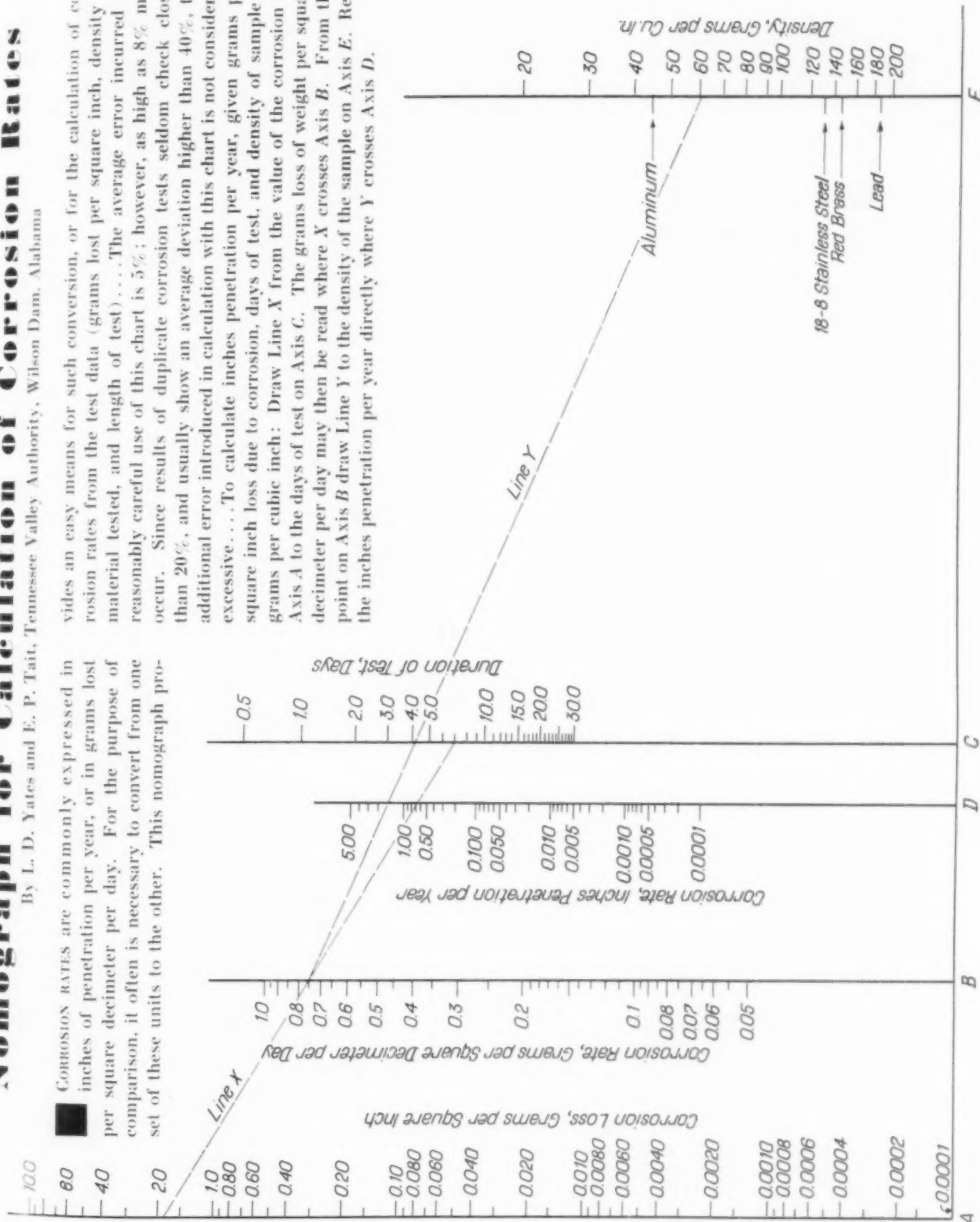
Professor of Metallurgy, to head division. Should be definitely known in field of metallurgy and able to make contacts with representatives of the industry. The university is ready to invest \$8000 — \$10,000 in equipment. \$4500 — \$5000. Middlewest. W-1037 C. ☉

Nomograph for Calculation of Corrosion Rates

By L. D. Yates and E. P. Tait, Tennessee Valley Authority, Wilson Dam, Alabama

CORROSION RATES are commonly expressed in inches of penetration per year, or in grams lost per square decimeter per day. For the purpose of comparison, it often is necessary to convert from one set of these units to the other. This nomograph pro-

vides an easy means for such conversion, or for the calculation of corrosion rates from the test data (grams lost per square inch, density of material tested, and length of test) . . . The average error incurred by reasonably careful use of this chart is 5%; however, as high as 8% may occur. Since results of duplicate corrosion tests seldom check closer than 20%, and usually show an average deviation higher than 40%, the additional error introduced in calculation with this chart is not considered excessive. . . . To calculate inches penetration per year, given grams per square inch loss due to corrosion, days of test, and density of sample in grams per cubic inch: Draw Line X from the value of the corrosion on Axis A to the days of test on Axis C. The grams loss of weight per square decimeter per day may then be read where X crosses Axis B. From this point on Axis B draw Line Y to the density of the sample on Axis E. Read the inches penetration per year directly where Y crosses Axis D.





Scrap salvage is a vital factor in the war effort. To be fully effective a scrap program must include methods for segregating and conserving critical alloying elements so urgently needed in the construction of tanks, guns, ships and planes.

Ferrous and non-ferrous metal scrap should be collected in separate containers at the machine where they are generated. Each class of high-speed

tool steel and each type of constructional alloy steel should likewise be kept separate so that the alloy content can be returned to service.


Remember, — alloy scrap which is segregated, classified and labeled according to type and composition is a vitally important commodity today—and urgently needed to augment primary supplies of Nickel, molybdenum, tungsten, etc.

The metallurgical experience of our technical staff is available to aid you in these and other phases of metal salvage.

KEEP SCRAP MOVING INTO WAR PRODUCTION!

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET
NEW YORK, N. Y.

Metal Progress; Page 1060

The round-table discussions on war products at the  convention developed so much information that the contributors have been solicited to release their "off-the-record" remarks for general publication. In the following pages are the formal statements made at one of the meetings

Saving Alloys in Steel

by Using "Addition Agents"

Preliminary Note by the Editor

■ "CRITICAL POINTS" in *Metal Progress* for November 1939 contained this item:

"Circulating about the National Metal Congress in Chicago it takes no Walter Winchell to hear things about new combinations of steel deoxidizers and grain refiners that confer interesting—even remarkable—properties to low alloy steels. (Maybe this is one commercial application of the physico-chemical information gathered over the last decade about the action of minor elements on dissolved gases and carbides.) Time was, about a generation ago, when we talked about the action of silicon and manganese with considerable confidence. Aluminum was also used—rather furtively, for some fussy customers thought it was harmful. Then came vanadium and titanium with their grain-refining and toughening functions, calcium, zirconium, columbium—even nitrogen—all added on occasion to control oxygen, sulphur, carbon, grain size. The newest developments now utilize mixtures of three or more of these old and new metals in one ferro; they are added to steel made by alloy practice, timed as carefully as a European ultimatum. The result, at least in standard test pieces, is a fine-grained, tough steel, with good hardenability even with low alloy content—certainly a unique combination."

In the intervening time boron has been added to the alloying list, and—except by special permission of the War Production Board—vanadium removed. So at present we have special ferro-alloys for addition agents of seven general types (balance is iron in all alloys) of

which the last three containing vanadium are restricted:

ELEMENT	A	B	C	D	E	F	G
Aluminum	7%	—	15%	13%	6%	10%	12%
Boron	0.5	11	1.5	0.5	0.5	0.2	0.2
Calcium	10	—	—	—	—	—	—
Manganese	—	—	20	8	—	—	—
Silicon	35	3	25	—	35	—	—
Titanium	10	—	15	20	10	15	20
Vanadium	—	—	—	—	6	—	—
Zirconium	4	—	—	4	10	25	13

A great deal of development and promotional work has been done on these and other addition agents by Vanadium Corp. of America, Union Carbide & Carbon Corp., Molybdenum Corp. of America, and Titanium Alloy Mfg. Co. Likewise, numerous trials by steel makers have established their position in modern metallurgy, and proved that they will be of prime aid in economizing our short stocks of other alloying elements. While trade names have not been used in the discussion, it should be remembered that specific results quoted are for the use of a specific agent—in other words the seven types of alloys are not fully interchangeable.



■ IT IS WELL KNOWN that practices now employed by steel producers in making any of the common alloy steels vary considerably from shop to shop. It is also a generally conceded fact that when an attempt is made to adopt in one shop a practice which has given

excellent results in another shop, a miserable failure may result, because of unseen, unknown and therefore uncontrollable variables. It is, for this reason, impossible to lay down specific requirements for using the special alloy addition agents in regard to such items as furnace practice or deoxidation practice, or to be specific on the exact quantities of alloy to be added. Based on many practical experiments, it is however possible to enumerate the precautions which must be taken and possible changes in practice which must be made in order to use the special alloys in practical steel making.

The special alloy addition agents, often called "intensifiers", are not cure-alls in any sense of the word, and cannot compensate for improper or careless steel-making practice, any more than the addition of any of the old alloys, such as nickel or chromium, will compensate for poor practice. They should be viewed in the same light as any other alloy added to secure specific properties of the steel, and therefore all refinements of practice and precautions which experience has proved to be necessary for the successful production of alloy steels must be also carried out in the production of the specially treated steels. Furthermore, since all of these special alloy addition agents are easily oxidized, it may be necessary to exercise somewhat greater care in their use.

In general, therefore, special alloy addition agents require somewhat more attention to details of practice than is normally used in the production of the average alloy steel.

It has been general practice to produce fine-grained heats of treated steels, and therefore very little or no data are available on coarse-grained heats. Further discussion will therefore be confined to fine-grained heats only.

The major portion of the experimental work has been performed by making additions to the steel as it is teemed into the ingot mold. In this way a direct and positive comparison of treated and untreated steel could be made on exactly the same base composition, thereby eliminating otherwise unavoidable variables involved in the comparison of two or more heats, due to differences in chemistry, grain size or unknown characteristics. A comparatively few of such

How to Use These Addition Agents

By Frederick M. Washburn
Superintendent of Testing
Wisconsin Steel Works
International Harvester Co.
South Chicago, Ill.

direct experiments gave information which otherwise would have required average results from a considerable number of full heats in order to iron out variables due to differences in composition and grain size.

The above practice of making ingot mold additions of these special alloys has worked out very well for experimental work, and the results have usually been excellent. It is rather difficult to make the additions so as to insure uniform distribution throughout the ingot and considerable care and skill are required to make the additions in the correct amounts and at the correct time. The use of such a practice on a production basis would necessitate additions to as many as 50 ingots from a large openhearth heat; even though the greatest care was exercised, it would be impossible to be assured of uniform distribution of the alloy from ingot to ingot, or from top to bottom of each ingot. Therefore, from a practical production standpoint, all additions of these special alloys must be made *in the ladle* rather than in the ingot mold, thus producing a full heat of the treated steel.

Without theorizing about the mechanism of the beneficial effects, it has been found in practice that the special alloy additions are extremely sensitive to the concentration of oxygen or oxides in the liquid steel. In other words, the steel to which they are to be added must be very thoroughly deoxidized, and *kept* very thoroughly deoxidized; otherwise part or all of the beneficial effect may be lost.

Normal fine grain, alloy, steel-making practices generally produce metal which, because of treatment in the ladle with strong deoxidizers (ordinarily aluminum or an alloy thereof) is low in oxygen content, or low in content of oxides reducible by the special alloy agents. Therefore, because the agents are easily oxi-



dized, a heat to which they are to be added must be handled in the furnace with full attention to all precautions and care normally used on fine grain, alloy practice, given the same furnace deoxidation, and given at least the same final treatment in the ladle with strong deoxidizers. The addition of the special alloy agent is then made in the ladle, immediately after the addition of the strong deoxidizers.

It is highly important that the special alloy be added last. Otherwise, lacking the protection afforded by the strong deoxidizer, the special alloy may pick up or combine with enough oxygen to render it ineffective as an alloying agent. It is also important to make certain that the special alloy addition is made to the ladle soon enough to insure thorough mixture, as otherwise erratic results may be obtained from first to last ingot of the heat, due to varying concentration of the special alloy.

Any abnormal conditions of furnace practice, furnace deoxidation, tap, ladle deoxidation, or teem which will cause an abnormally high concentration of oxygen or oxides in the steel may have a profoundly detrimental effect on the ability of these special alloys to function as desired. For example, a heat with a running stopper and a spraying stream into the ingot mold may pick up enough oxygen, due to the extra contact between liquid steel and air, to mean the loss of a part or all of the beneficial effect, depending somewhat upon the special alloy used.


This statement will be further elaborated in the following: In the case of all of these special alloy addition agents, addition of an excess beyond a certain optimum quantity confers only minor benefits in comparison to the amount added. Furthermore, addition of quantities over the optimum does not, in some cases, have any detrimental effect. Certain of these special alloys may therefore be added to excess, beyond the quantity required to produce the minimum desired effect. If this can be done as a standard practice, some of the alloy may be lost by oxidation due to unforeseen difficulties, and yet enough alloy will remain to obtain the benefits desired. In other words, it is sometimes possible to add a considerable excess of alloy as an insurance against unforeseen variations in practice which may occur in the best of steel-making shops.

On the other hand, some of the special alloys have rather sharply defined practical maximum concentrations (*Cont. on page 1098*)

What Alloys Can Be Saved?

By Walter Crafts

Union Carbide & Carbon Research Laboratories
Niagara Falls, N. Y.

 THE PRIMARY FUNCTION of special alloying addition agents is to contribute greater hardenability. There is nothing secret or occult about this. As in the case of conventional alloys, nickel, chromium, molybdenum, manganese or silicon, the increased hardenability conferred by special alloys containing boron permits the development of higher strength in medium and large sections without sacrifice of ductility and toughness.

It has been demonstrated by Janitzky and others, that maximum toughness and ductility depend on, first, introducing sufficient alloys so that the steel will harden on quenching to a full martensitic structure and, second, tempering the fully hardened steel to a given strength. Ductility will then be of the same order regardless of what alloys were used to obtain the required hardenability. The essential yardstick for substitution of alloys in heat-treating steel is, therefore, a measure of hardenability, such as the Jominy test. Other properties are also valuable, but to simplify the present brief discussion, they will be neglected, as will also carburizing steels, toolsteels, or other special steels.

Hardenability as a yardstick for substituting one steel for another has been utilized to a major degree by the American Iron and Steel Institute's committee in their development of the National Emergency Steels. They also utilized the principle outlined by Grossmann: That smaller amounts of a number of alloys are more economical of alloys than a large amount of one or two alloys.

These same principles also govern the types of steel in which the special deoxidizing alloys may be used to advantage. In general, on account of the interchangeability of alloying elements in the common grades of heat-treating steels, the special treatment may be applied best to those requiring significant additions of alloys that are relatively scarce. For the present discussion it is assumed that the demand now exceeds the supply for *all* alloys, and that they are ranked as follows in order of increasing availability: Nickel, molybdenum, chromium, manganese, and silicon. Even without the use of "intensifiers" the NE8000 steels have already

eliminated a large amount of nickel, and the new NE9000 steels have greatly reduced the proportion of molybdenum. These savings have been made through more effective use of residual alloys derived from scrap, and from the use of increased amounts of the more plentiful manganese, silicon, and chromium. It is now expected that the special alloying agents will permit *further* saving of nickel and molybdenum, and will also relieve the growing demand for manganese and chromium.

On the basis of Jominy hardenability tests of comparable steels, it has been found that the treatment with special alloys is equivalent to approximately 1.25% nickel, or 0.25% molybdenum, or 0.35% chromium. This degree of increase of hardenability is not sufficient to make specially treated carbon steels containing no alloy the equivalent in hardenability of the common low alloy S.A.E. and NE steels, but it is enough to reduce the requirement for critical alloys in alloy steels. One outstanding exception to this statement is the carbon-molybdenum S.A.E. 4000 series in which the same hardenability could be obtained from special treatment as from the molybdenum content.

The NE steels of medium hardenability may be divided into those that obtain most of their alloys from residuals in the scrap, such as NE9400, and those that require virgin alloy additions, such as the plain manganese NE1300 type, the manganese-molybdenum NE8000 to 8400 types, the nickel-chromium-molybdenum NE8600 to 8900 types, and the manganese-silicon-chromium NE9600 type. The special deoxidizing alloys appear to be particularly suited to reducing the amount of virgin alloy additions in the latter group. The hardenability of NE8339, for example, is virtually unchanged when the special treatment is substituted for the molybdenum. In the same way, a part of the chromium or manganese might be saved in NE9600 steel by the special treatment. In NE1300 it would be possible to save about 0.60% manganese, and in NE8600 and 8900 the saving might amount to one-third or more of the nickel, chromium, and molybdenum.

Molybdenum is now probably the most critical element used for alloying in heat-treating NE types of steel, and it is probable that it could be reduced or entirely eliminated from these steels by the special treatment without increasing the demand for manganese, chromium, and silicon. In other steels that do not require additions of nickel or molybdenum, the

special treatment might be used to reduce the use of manganese and chromium.

At higher levels of alloy content, each additional unit of an alloy that is added produces a proportionately smaller increase in hardenability than the same amount of alloy at the lower level. This factor of diminishing returns becomes more evident in the very deep-hardening steels, which require more of the critical alloys than can be effectively derived from selected scrap. The necessary further additions of nickel, chromium, and molybdenum are not only less efficient than the residual amounts in increasing hardenability, but the additions must be made from virgin metal. Thus, in the interests of conservation, it may be advisable, when a critical amount of strategic alloy is already present, to obtain the desired increase in hardenability by the special treatment.

For example, NE9450 steel containing 0.30% chromium, 0.30% nickel, and 0.12% molybdenum can be made equivalent by special addition agents to NE8949 or 9550 which contain 0.50% chromium, 0.50% nickel, and 0.20 or 0.35% molybdenum. In view of the current scarcity of nickel and molybdenum, and relatively greater availability of chromium, it is notable that the special treatment of NE9650 containing 0.50% chromium and no molybdenum, will also give hardenability of the same high order. In these examples the special treatment can save not only almost half of the total nickel, chromium, and molybdenum but almost eliminate the need of virgin additions of alloy.

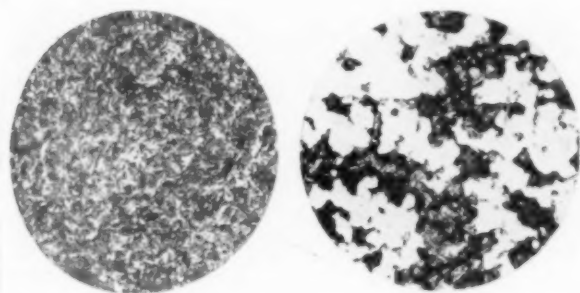
In summary, experience has taught that the special alloy treatment is the equivalent of new alloy in its effect on hardenability. It has been demonstrated in the NE steels that one available alloying metal can be readily substituted for another that is scarce (in order to utilize available materials) and that smaller amounts of a greater number of alloys are more effective than a large amount of any one. The special treatment may, therefore, be applied in the same manner as another alloy in order to substitute for more critical alloys and to permit greater savings in the use of all alloys. The available national supply of alloys at the present time is such as to suggest that, in order to obtain a medium degree of hardenability, the special treatment should be applied primarily to manganese-silicon steels. For deeper hardenability, the special treatment should be applied to chromium-nickel-molybdenum steels whose alloys are derived mainly from scrap.

What Types of Steel Can Be Benefited?

By A. W. Demmler
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PROBABLY the most convincing way to answer the question "What Types of Steel Can Be Benefited?" is to quote mechanical tests on split heats using various alloys, one portion cast direct and the other portion after alloying with addition agents. In this I will limit myself to figures derived in our own laboratories from commercial heats of steel treated with "intensifiers" made by Vanadium Corp. of America.

Many of the improved properties of alloy



1055 (Left) Transforms Completely in 5.2 Sec. at 1030°F., Whereas the Same Steel With Addition Agents (Right) Requires Much More Than 10 Sec.

treated steels are associated with their greatly increased hardenability—a matter discussed in detail later by Mr. Comstock. To the modern metallurgist, hardenability and speed of transformation are inversely proportional. That is to say, a plain carbon steel which typically transforms from austenite to martensite at a high rate of speed is a

Heat Treatments:

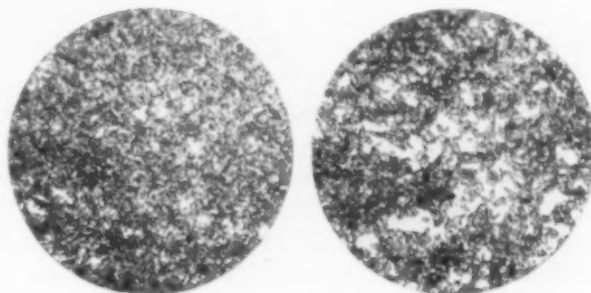
A: Normalize, pseudo carburize at 1675° F., quench from pot in oil, temper at 325° F.

B: Normalize, soak at 1700° F., furnace cool to 1550, oil quench, 450° temper, air cool.

C: Normalize, oil quench from 1475° F., temper at 300° F., air cool.

D: Same as A, except temper at 350° F., air cool.

shallow hardening steel—has low hardenability. On the other hand, an alloy steel which transforms at a slow rate of speed is a deep hardening steel—has high hardenability. Micro-examination shows that the addition agents slow down the rate of transformation markedly. For instance, commercial S.A.E. 1055 steel transformed fully in 5.2 sec. at 1030° F.; the same steel, treated, did not completely transform in 10 sec. Again: S.A.E. T1340 transforms



Additional Time Required to Transform In Steels Containing Reaction Alloys Shown by S.A.E. T1340; Untreated (Left) Transforms Completely in 40 Sec. at 910°F.; Treated (Right) Contains Some Austenite (Clear Areas) After 300 Sec. (700 for complete transformation)

nearly completely at 910° F. in 40 sec.; when treated it retains considerable austenite after 300 sec. How these facts influence a Jominy end-quench curve is shown in the graphs on pages 1068 and 1069.

Hardenability is a real and genuine tool for the metallurgist but does not mean so much to the designing engineer. In any case, a clear understanding of the precise application is necessary before anyone can make a sensible recommendation of a substitute. Hardenability is not necessarily a guide to wear resistance, or to

Table I—Effect of Reaction Alloys on Carburizing Steels

STEEL	ALLOY ADDED	HEAT TREATMENT	TENSILE PROPERTIES			BRINELL HARDNESS	IZOD IMPACT	HARDENING DEPTH (a)
			ULTIMATE	ELONGATION	REDUCTION			
X1020	No	A	100,200	23.0	69	217	106	0.08
	Yes	A	133,500	17.5	63	302	30	0.60
5120	No	B	113,000	21.5	55	232	—	0.78
	Yes	B	132,600	17.5	61	290	—	1.07
2512	No	C	153,000	16.8	55	321	41	0.75
	Yes	C	182,000	15.8	57	363	45	1.00
4620 (b)	No	D	126,600	23.0	58	255	71	0.45 (c)
	3 lb.	D	177,400	15.0	58	388	53	0.81
	6 lb.	D	196,000	15.0	58	393	48	0.98
	9 lb.	D	197,600	14.0	57	404	40	1.09

(a) Inches from end of Jominy end-quenched bar to Rockwell C-40.

(b) Basic electric steel with 1.30%

nickel (below the specified range of 1.65 to 2.00%).

(c) See end-quench curves page 1067.

Table II — Effect of a Reaction Alloy on Semi-Deep Hardening Steels

STEEL	ALLOY ADDED	HEAT TREATMENT	TENSILE PROPERTIES			BRINELL HARDNESS	IZOD IMPACT	HARDENING DEPTH	
			ULTIMATE	ELONGATION	REDUCTION			To C-50	To C-40
S.A.E. 5040	No	A	249,500	6.5	22	461	6	0.24	0.35
	Yes	A	275,200	12.5	49	514	16	0.49	0.69
S.A.E. 5140	No	A	245,800	10.0	38	464	12	0.31	0.54
	Yes	A	258,800	8.5	36	477	18	0.52	0.76
A 4063	No	A	328,600	7.0	23	578	—	0.35	0.44
	Yes	A	336,800	7.0	26	587	—	0.95	1.23
NE8442	No	A	288,700	9.0	40	522	9	0.56	1.00
	Yes	A	291,000	9.0	38	522	16	2.8	>3.0
NE9260	No	B	218,600	9.5	29	423	9	0.49	0.71
	Yes	B	227,600	8.5	30	444	10	1.22	1.43

Heat Treatments: A. Normalize, oil quench, draw at 450° F. in preliminarily machined sections.

B. Normalize, oil quench, draw at 900° F. in 1-in. rounds.

properties at elevated temperatures. Without a knowledge of the pertinent considerations surrounding a given application, one might recommend—in the interest of conservation of strategic materials alone—a substitute steel containing an appreciably higher carbon content, and find himself facing cracking and other troubles in heat treatment, yet a less drastic quench might not be feasible for the lower alloy substitute chosen. Here is an excellent spot for a steel treated with a special addition agent or reaction alloy, which may well simplify the hardening cycle on a specific job and, from our observations, reduce cracking problems.

The question of *amount* of reaction alloy is important, not only from a cost standpoint but also from the effect on the properties of the

steel. While the available alloys vary considerably in both of these respects, the last four lines of Table I and the end-quench curves of these same steels show that when conditions are right the *exact* amount of addition is not so critical. The steels are special nickel-molybdenum analyses, lower than standard S.A.E. 4620 in nickel, made in a basic electric furnace, and containing 3, 6 and 9 lb. per ton of intensifier. While electric steels frequently require an addition somewhat in excess of that common to open-hearth practice, an addition of 9 lb. per ton represents a considerably larger quantity than is recommended, yet no adverse effects are observed in the hardenability curves. Since hardenability need not be the whole story where excesses are involved, a look at the test prop-

Table III — Tests on Laboratory Heats of NE9420 and NE9440

STEEL	ALLOY ADDED	SIZE TREATED	HEAT TREATMENT	TENSILE PROPERTIES				BRINELL HARDNESS	IZOD IMPACT	HARDENING DEPTH
				ULTIMATE	YIELD	ELONGATION	REDUCTION			
NE9420	No	½ in.	A	136,100	92,000	17.0	58	273	66-60	0.10 (a)
	Yes	½ in.	A	214,600	190,000	11.5	52	421	35-32	0.48 (a)
	No	½ in.	B	198,500	156,400	12.0	46	414	27-25	0.10 (a)
	Yes	½ in.	B	215,000	185,000	12.0	53	424	32-31	0.48 (a)
	No	1 in.	C	102,000	83,200	24.0	68	217	111-111	0.10 (a)
	Yes	1 in.	C	141,400	136,400	16.5	62	304	78-76	0.48 (a)
	No	1 in.	D	113,800	95,900	21.0	68	241	94-90	0.10 (a)
	Yes	1 in.	D	147,100	143,100	17.0	62	306	71-71	0.48 (a)
NE9440	No	½ in.	E	270,400	228,600	8.0	33	515	13-18	0.33 (b)
	Yes	½ in.	E	268,600	232,500	8.0	33	500	16-17	0.63 (b)
	No	1 in.	F	162,900	148,100	14.5	52	341	47-42	0.33 (b)
	Yes	1 in.	F	171,000	166,600	14.0	52	347	36-36	0.63 (b)

(a) Inches from end of Jominy end-quenched bar to Rockwell C-40; (b) To Rockwell C-50.

Heat Treatments:

A: Normalized 30 min. at 1750° F.; oil quenched after 20 min. at 1575° F.; drawn 1 hr. at 450° F.; air cooled; treated in preliminarily machined sections.

B: A, but water quenched from 1550° F.

C: Normalized 30 min. at 1750° F.; oil quenched after 30 min. at 1600° F.; drawn 1 hr. at 900° F.; air cooled; treated in 1-in. rounds.

D: Same as C, but water quenched from 1575° F.

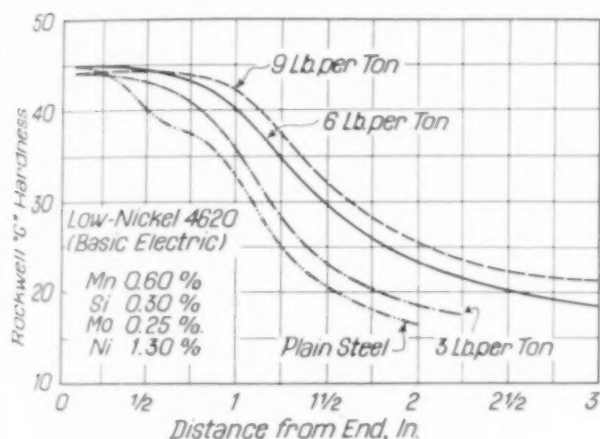
E: Normalized 30 min. at 1650° F.; oil quenched after 20 min. at 1525° F.; drawn 1 hr. at 450° F.; air cooled.

F: Normalized 30 min. at 1650° F.; oil quenched after 30 min. at 1550° F.; drawn 1 hr. at 900° F.; air cooled.

erties of these same steels will be enlightening. In the group at the bottom of Table I we find a marked increase in strength for all additions, with fine ductility and toughness in all instances.

A comparison of all the steels in Table I on the basis of equal strengths would be of questionable validity since in typical carburizing heat treatment cycles the tempering temperature is always low.

It would appear to be clear from the above data, necessarily fragmentary because of time limitations in this presentation, that carburizing steels, both carbon and alloy, are benefited in



Surplus of Vanadium Reaction Alloy is not Detrimental to Hardenability. Basic electric steel; commercial heat

their mechanical properties to a remarkable degree.

Next for the "semi-deep hardening" steels. Table II summarizes some figures on this class of materials. The first two lines show how the intensifier improves the low alloy S.A.E. 5040 steel (0.60% chromium), bringing it up to the hardenability of the much more highly alloyed S.A.E. 2340 and 3140. Strength is up — even ductility and Izod value. Treated S.A.E. 5140, with nearly double the chromium, is also benefited by the same alloy treatment, but hardly to the remarkable degree of S.A.E. 5040. Tensile properties of the carbon-molybdenum or Amola steel (A4063) in preliminarily machined sections are relatively unaffected by the treatment, although its hardenability is greatly improved, as shown by the curve on page 1068. The same can be said of NE8442 (manganese-molybdenum) and the silico-manganese spring steel NE9260.

The conclusion from this and a great mass of other data is that the tensile properties of the semi-deep hardening steels are increased by

special alloy treatment in proportion with the gain in hardenability when section size is considered, with no deterioration — in fact, often a substantial gain — in the ductility (especially at high hardnesses) as measured by elongation and reduction of area in the tensile test piece, and in notched-bar toughness as measured by the Izod impact test.

Finally let us consider the newest of the National Emergency Steels designed for the utmost saving in scarce alloys. The data in Table III are for Ajax induction furnace heats. (All preceding material came from commercial heats.) The intensifier effects are somewhat astounding. Here is a steel whose basis (NE9420, and on the low side in silicon) is certainly a water quenching grade for ordinary temperatures, but with the intensifier it quenches in oil at least in 1-in. section! Results of both oil and water quenches have been recorded with low and medium tempering temperatures. For the 450° F. temper the specimens were hardened in practically the same size as the final test piece while for the 900° draw 1-in. sections were heat treated. Commercial material, under test, fully supports the properties of Ajax heats.

The same table contains a little data on NE9440 steel melted in a 30-lb. Ajax furnace. The Jominy hardenability is recorded. Incidentally these, as well as the others reported, are fine-grained base steels. Since this composition has ample hardening capacity in preliminarily machined sections, little difference in properties is observed for this condition but differences begin to show up in the 1-in. sections.

Now let us sum up the remarks: There is no question that hardenability is increased by the various intensifier alloys and this fact is not confined to merely a few grades of steels. It includes the carbon and alloy carburizing grades, the semi-deep hardening alloys, and the NE low alloy steels. Data on performance in service are collected, of necessity, more slowly than laboratory data, but the outlook is very encouraging. At high hardnesses, the ductility and toughness are very good in these treated steels. In the lower hardness ranges, mass benefits must be recognized, which may permit of some simplification in the quench and perhaps higher tempering temperatures. Distortion and cracking bear some relation to such conditions.

Today the real answer to any new steel is performance. Intensifiers have already won their spurs in a number of applications.

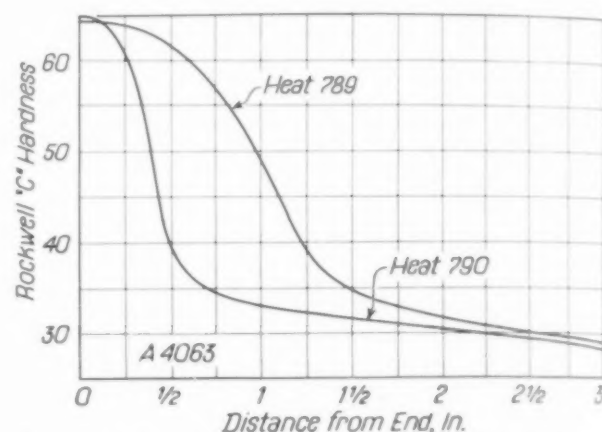
Extra Hardenability Obtainable in a Treated Steel

By George F. Comstock
Metallurgist
The Titanium Alloy Mfg. Co.
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FOR THIS DISCUSSION of the benefits obtainable in various steels by the use of the boron-bearing deoxidizers, we are fortunate in having available a summary made by a Committee of the American Iron & Steel Institute which has studied the subject for several months. Since this Committee included practically all the pertinent data acquired in this country on the use of these alloys, both in laboratory research work and in large-scale commercial trials, I can do no better than select some appropriate items from the Committee's conclusions.

As already stated by Mr. Crafts, the most prominent and important effect of the proper use of these boron-bearing alloys is to increase the hardenability of the treated steel. Other effects on physical properties such as tensile strength, yield strength, ductility, and notched-bar impact resistance are chiefly, though perhaps not entirely, the result of the increased hardenability. It is important therefore to understand just what is meant by the term "hardenability", and since it is even yet confused at times with "hardness", it may be worth while to explain that "hardenability" consists essentially of the ability to become harder after *rapid* cooling from a reasonably high temperature, whereas "hardness" is more closely allied to the ability to become hard after the comparatively *slow* cooling from similar temperatures which generally occurs in the last stages of steel manufacture. A steel that is harder in the normal (slow cooled) condition may actually have less hardenability (or require a more drastic cooling treatment in order to attain a given degree of hardness) than a steel that is normally softer. "Hardness" in the above sense is more closely proportional to the carbon content; "hardenability" is a function also of the alloy content and the grain size, but all commercial steels possess this property of hardenability to some degree, except perhaps those with very low carbon contents that are used chiefly for sheets and wire.

Since the hardening of plain carbon steels or low alloy steels by heat treatment is accomplished by *rapid* cooling from a temperature above the critical point, and does not occur on slow cooling, the *rate* of cooling controls whether a given steel hardens usefully or does not harden to any great extent. The rate of cooling that must be exceeded for hardening to occur is thus a measure of the hardenability. When any given piece of hot steel is cooled rapidly, or quenched, the outside surface of the



Commercial Amola (Carbon-Molybdenum) A 4063 Steel; Plain Heat 790; Alloy Treated Heat 789, (Demmler)

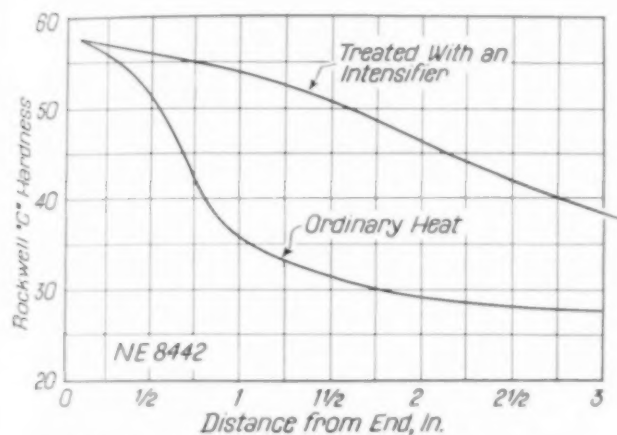
piece obviously has the highest rate of cooling, and has the best chance of being hardened. Unless the piece is very small, the inner portions cool with less rapidity as the distance from the outside increases, and toward the center of a sizable piece the rate of cooling is often too slow for hardening to occur. When testing specimens of standard size under standard cooling conditions, the depth or distance from the surface through which hardening occurs gives a very convenient measure of hardenability.

This is the basis of all present-day methods of hardenability testing, of which the Jominy end-quench method is probably the most practical and widely used. As is well known to members, the specimen is a round bar of standard size, quenched by a standard stream of water striking only on one end, so that the depth of hardening may be shown by making hardness tests at $\frac{1}{16}$ -in. intervals along the cylindrical surface, starting from the quenched end. Plotting the hardness against the distance from the quenched end gives a curve which shows the hardness values for all rates of cooling.

Results of this test are conveniently reported as the length of the specimen in sixteenths of an

inch which has hardened to Rockwell C-50 or higher. This is sometimes called the "Jominy value". If one steel has a higher "Jominy value" than another, the first of course has a greater hardenability, for it hardens to a greater depth.

Average results on this basis with steels containing 0.40 to 0.45% carbon and either about 1.15% manganese (special A.I.S.I. C-1341, high in manganese) or about 0.75% manganese with 0.65% chromium (A-5045) or 0.25% molybdenum (A-4042), made commercially in large



NE 8442 Has Its Hardenability Greatly Increased by Treatment With an Intensifier (Demmler)

heats, show Jominy values at Rockwell C-50 raised from around 3 for the untreated steels to around 6 or 9 for steels treated with the boron-bearing deoxidizers.

More highly alloyed or higher carbon steels, such as those with about 0.40% carbon and 1.75% manganese (NE1340) or others with 0.30% nickel and 0.30% chromium and 0.10% molybdenum (NE9440) and those with around 0.60% carbon, 0.90% manganese and high silicon (NE9260) or 0.25% molybdenum (A-4063) show increases in Jominy value from about 5 or 6 to 11 to 15 for the special alloy treatment.

Thus the treated steels of the lower alloy classes first mentioned, with Jominy values after special treatment of 6 to 9, can be made equivalent or superior in hardenability to these more highly alloyed steels. Still more highly alloyed steels are correspondingly affected by proper treatment with the boron-bearing alloys, the steel with about 0.50% carbon, 1.2% manganese, 0.50% nickel, 0.50% chromium, and 0.35% molybdenum (NE8949) being raised from average Jominy values of about 8 at the high hardness of Rockwell C-55 to over 40.

General experience, as well as the harden-

ability curves, indicates that with slow cooling rates, such as in normalizing, neither the hardness nor any other property of the steel is materially improved by treatment with these boron-bearing deoxidizers. The effects are most important for parts that are used in the quenched condition (without tempering or with only a slight tempering) at hardness of 300 Brinell (Rockwell C-32) or harder. With steel in such a condition that no appreciable separation of carbide from ferrite has occurred, there is a marked improvement in the character of the hardened structure, and the ductility and toughness are improved by the alloy treatment. This improvement disappears with softening or tempering at higher temperatures, whereupon the impact values of the treated steels may be even slightly lower than those of similar untreated steels.

Tensile properties are measured on test pieces of medium size (frequently machined from 1-in. bars after specified heat treatments) and the test results are of course very drastically affected by the hardening practice. If the tensile properties of two fairly similar steels are compared in a condition of heat treatment such that one steel hardens to a much greater depth than the other, the difference in properties may be enormous for very slight differences in composition. In steels of low hardening capacity, treatment with the boron-bearing alloys generally gives much higher tensile strength and yield point with quenched and drawn specimens, while in more readily hardenable steels the treatment with addition agents may improve the reduction of area and notched-bar impact resistance without much change in tensile strength.

As an illustration of the effects on tensile properties of the former class of steels, the following average results of tensile tests of a steel containing about 0.40% carbon and 0.75% manganese (A.I.S.I. steel C-1040), quenched in

	UNTREATED	TREATED WITH BORON-BEARING ALLOY
Yield point	91,000 psi.	227,000 psi.
Tensile strength	123,000 psi.	275,000 psi.
Elongation in 2 in.	19%	7.5%
Reduction of area	53%	35%

oil from 1550° F. and tempered at 450° F. may be cited, and show over 100% gain in yield point and tensile strength; the ductility of the treated steel was of course lower, since it hardened while the other did not. (Cont. on p. 1100)

"Sulphur prints" of steel sections are metallographic commonplaces, but the present authors extend the utility of this simple test to other inclusions in other metals by using gelatine coated paper soaked in a specific electrolyte, imposing a small current, and developing the print in suitable reagents.

Electrographic Methods of Surface Analysis

■ AN ELECTROGRAPHIC METHOD is one by which a small amount of material is removed from the surface of an object under the influence of an applied potential, and is driven into paper or some other porous medium where it may subsequently be detected and identified by any one of a number of suitable reagents. Methods of this general type have been developed by Glazunow¹, Jerkowsky², Arnold³, Fritz⁴, and Clarke and Hermance⁵. The reagents used in identifying the dissolved materials are usually the same as those employed in colorimetric spot testing, as described in references No. 6 to 13, inclusive. (See the bibliography on page 1076.)

Electrographic methods have certain definite advantages over other methods of testing. They are very rapid and the apparatus required is simple and inexpensive. One is able to get a distribution map of the surface of a specimen, the points of occurrence of a certain element being found as mirror images on the print. In cases where prints are made of homogeneous solid solutions, one print may serve for tests for a large number of elements, since single drops of a variety of reagents may be placed on the print and, in this manner, the presence or absence of each of these elements may be determined. Once the electrographic print has been made, it can often be dried and preserved as a permanent record of the surface of the specimen.

Perhaps the greatest advantage

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of such a method is that it can be made with but very little damage to the surface of the specimen.

Description of Technique

A schematic diagram of the apparatus used for making electrographic determinations is shown in Fig. 1. In this diagram are shown a source of current, a block upon which to place the paper, a means of applying pressure to a specimen in order to bring it into intimate contact with the paper, and an ammeter to determine the amount of current flow. Current supplied by a 6-volt storage battery or a similar direct current source is sufficient for making the prints. The cathode block, upon which the paper was placed, was of aluminum. Any flat conducting material would have been satisfactory as far as completing the circuit was concerned, but it was found that aluminum did not form colored products with many of the reagents and hence little interference could result from the block. Pressure can be applied by means of a clamping device or by placing sufficient weight upon the specimen to press it into contact with the paper. An ammeter was included in the circuit to make

sure that a sufficiently high current density was used to dissolve material rapidly from the surface of the specimen. In certain cases where the specimen was very large or was not flat, it was found more convenient to place the paper upon the specimen, and then place a piece of aluminum sheet or foil upon the paper to act as the other electrode.

In brief, the method used consists of placing a piece of the paper saturated with a suitable electrolyte on the block, pressing the specimen into intimate contact with the paper, making the specimen anodic so that material from the surface of the specimen will be dissolved and picked up in the paper, and then washing the paper and developing it by means of suitable reagents.

Selection of Paper—Experiments with various kinds of papers revealed that a gelatin-coated paper (Eastman's Imbibition Paper) was the most satisfactory, since diffusion within the gelatin layer is very slow—the ions of the material to be analyzed remain at their points of entry with the result that a very clear-cut print is produced. Also, it was found that as the current continued to flow, an actual concentration of material would result in the gelatin at the points of entry. In this manner, the concentration could be increased to a point such that a reagent of a given sensitivity would detect the material, whereas if the ions diffused away, a high enough concentration might never be reached. It is also possible to detect and determine the location of cer-

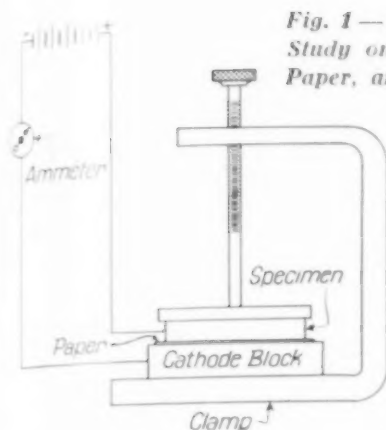


Fig. 1 — Simple C-Clamp Presses Surface Under Study on a Piece of Reagent-Treated Gelatin Paper, and a Small Direct Current Is Imposed

tain elements by the formation of colored but soluble products which would disperse very rapidly in a dense filter paper. It was also found that when different elements, forming differently colored compounds with a given reagent, occurred at different locations on the surface of the specimen, the diffusion in the gelatin layer was so slow that the locations could be very close together and yet no interference would result. Thus an accurate map of the occurrence of certain elements on the surface of the specimen could be obtained.

Inert, Conducting Solution — Experiments showed that the most satisfactory prints were obtained by saturating the gelatin paper with an aqueous solution of a neutral salt and subsequently developing the paper with the proper reagent. It was found that if the paper was impregnated with the detecting reagent *before* the current was passed, the current would often decompose the reagent to form colored products which would confuse the test. Also, when the paper is impregnated with a solution of a neutral salt, different reagents can be applied to different parts of the print with the result that a number of tests can be made on one print. In addition, the solution of elements which might interfere with a certain test can often be prevented by the choice of a suitable electrolyte with which to saturate the paper.

Current Requirements

The amount of current depends on the size of the specimen, the elements to be detected, and the solution which is used in the paper. Naturally, if the element to be detected

forms the most anodic areas on the surface in the electrolyte chosen, no applied current would be required to drive this element into the paper. However, it was found that even in these cases the electrographic method was applicable, since the passage of current greatly hastened the process and produced greater concentrations in the paper in shorter periods of time. On the other hand, if the areas it is desired to detect are not the most anodic on the surface, in the electrolyte used, a current flow is necessary to force the material

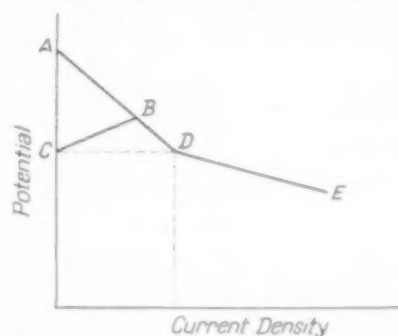


Fig. 2 — If Two Substances With Open-Circuit Potentials A and C Are Short Circuited in an Electrolyte, the Anodic Substance A Will Be Dissolved by Self-Generated Current. To dissolve the cathodic substance C, a separate current must be imposed to polarize the potential to some point on DE

from the surface of the specimen into the paper.

Since the solution potentials of the various elements vary in different solutions, different current densities will have to be used, depending upon the elements to be detected and the electrolyte. As a matter of fact, it was often found that a lower current density could be used to force a certain element from the specimen into the paper if a change were made in the electrolyte. However, with each set of conditions of element and solution, a definite minimum current density must be exceeded before the element is driven from the specimen into the paper. This value is apparently the current density necessary to polarize the entire specimen to the open circuit potential of the most cathodic area.

Without such polarization, the most anodic area would be dissolved and a more cathodic material which was present in the surface of the specimen would not be transferred to the paper and hence would not be detected.

Figure 2 shows the conditions which might be found to exist on the surface of a specimen and demonstrates the necessity of applying a current to detect a certain element in the presence of a more anodic element. For example, let us assume that we have a specimen of sheet material A which contains an inclusion of a more cathodic material C. The open-circuit potentials of the two are denoted by the points A and C respectively in Fig. 2. If these two materials are short circuited and a liquid circuit is furnished, as would be the case if the sheet specimen containing the inclusion was placed on the gelatin paper saturated with an electrolyte, the anodic material will polarize along the curve A-B and the cathodic material will polarize along the curve C-B until point B is reached. At this point the potential of the entire specimen will be that potential corresponding to B (neglecting the small *ir* drops which exist), and a self-generated current, also corresponding to B, will be flowing in such a direction that only the anodic material will be dissolved. Thus, without an applied current the more cathodic inclusion would not be dissolved directly and hence could not be detected.

However, as current is applied to the specimen, it will polarize along the curve B-D-E. Until point D, which corresponds to the open-circuit potential of C, is reached, only the anodic material A will be dissolved. Beyond point D, both A and C will be dissolved, unless, of course, C is passive. Thus, by means of the passage of current in an electrographic test, practically all elements may be forced from the surface of a specimen into the gelatin paper, regardless of their open-circuit solution potentials. (Considerable study has been given to polarization phenomena and polarization curves of various materials in a number of solutions. See articles cited as No. 14 to 19 inclusive in the bibliography, page 1076.)

It was found best to apply a cur-

rent density definitely on the high side so that a large amount of the element would be transferred to the paper in a relatively short time. To obtain such a current density, the total current would have to be increased as the area of the specimen in contact with the paper is increased. No definite time of current flow can be set up, since this factor will depend on the amount of the element present and the sensitivity of the reagent used. In general, it was found that about 30 sec. produces satisfactory results, although sometimes a more positive test was obtained by increasing the time. It was also found that the time of current flow was sometimes limited by a drying-out of the paper as a result of the current flow.

formed, the electrolytes which were used, and some of the interferences which might be encountered.

In the search for reagents or "developers", it was found that many of those which are satisfactory for ordinary qualitative and quantitative analyses or for spot tests would not answer for electrographic tests. Tests using certain of these reagents require techniques which are impractical when the material to be detected is present only in small quantities in a gelatin layer. The dithizone test for lead or silver is unsatisfactory for this reason. Again, some reagents depend upon white or very lightly colored precipitates, or upon small color variations or differences which are not readily visible against a paper background. In this regard,

are not readily discernible against the paper background.

Other reagents used in chemistry are specific for a certain element only if it is known that a large number of other elements are absent. Experiments revealed that chemical or mechanical separations could not be carried out satisfactorily in the gelatin paper. For this reason, the tests for aluminum using alizarin, aluminon, and cyanine were unsatisfactory electrographic tests. Still other reagents require heat or substances which would destroy the gelatin paper. Also found to be unsatisfactory were certain reagents which in themselves were colored, since they were often absorbed by the gelatin layer, or by the hydroxides of certain elements which might

be present, and could not be readily washed from the paper. In addition, the green fluorescence produced by morin in the presence of aluminum was found to be an unsatisfactory test for this element.

The best reagents are naturally those which are highly sensitive and are specific for the element being detected. Where reagents of lower sensitivity have to be used, the time of current passage must be increased to get a sufficient concentration of an element to produce a positive test. As in other forms of analysis, a negative test might not prove that a certain element is absent but merely that an adequate concentration of it has not been obtained in the gelatin layer.

Table I—List of Satisfactory Electrographic Tests

ELEMENT SOUGHT	ELECTROLYTE	DEVELOPER	COLOR	INTERFERING ELEMENTS
Bismuth	5% KNO ₃	10% KI	Orange	Lead
Cadmium	5% KCN acidified with H ₂ SO ₄	H ₂ S gas	Yellow precipitate	Those forming black sulphides
Chromium	5% K ₂ SO ₄ or 5% KNO ₃	3% H ₂ O ₂	Yellow changing to violet in developer	
Cobalt	5% NaF	Saturated acetic KCNS	Blue	Copper or nickel in very large quantity
Copper	5% Rochelle salts or 5% KNO ₃	5% ammoniacal benzoin-oxime in alcohol	Green	
	5% KNO ₃	0.5% alcoholic rubeanic acid	Black	
	5% KNO ₃	NH ₃ gas	Blue	
	5% KNO ₃	5% K ₂ Fe(CN) ₆	Red	
Iron	5% KNO ₃	5% K ₂ Fe(CN) ₆	Blue	
	5% K ₂ SO ₄ or 5% KNO ₃	5% K ₂ Fe(CN) ₆	Blue	Chromium
	5% KNO ₃	5% KCNS	Red	
Lead	5% KNO ₃	1% K ₂ CrO ₄ in normal CH ₃ COOH	Yellow	Silver
	5% KNO ₃	10% KI	Yellow	Bismuth
Molybdenum	5% K ₂ SO ₄ or 5% KNO ₃	Saturated solution of potassium ethyl xanthate in 5% H ₂ SO ₄	Purple	
Nickel	5% KNO ₃	1% dimethyl glyoxime in concentrated NH ₄ OH	Scarlet	Iron, Cobalt
Silver	5% K ₂ SO ₄	K ₂ CrO ₄	Brick red	

Selection of Reagents

A large number of reagents were tested in an effort to find ones which were specific for certain elements in the presence of a number of other elements, but by far the greater number were unsatisfactory. The reagents found to be practical for the detection and identification of a number of elements are given in Table I, along with the color of the products

it was found that tests utilizing the formation of colored insoluble borates, bromides, carbonates, cyanides, fluorides, hydroxides, iodates, oxalates, phosphates, silicates, sulphites, and tartrates were generally unsatisfactory because the compounds formed are too light in color and do not give sufficiently positive tests. The diphenylcarbazide test for magnesium is also unsatisfactory because the color variations involved

The "Test Block" Technique

In order to determine whether or not a certain reagent would give a specific test for an element in the presence of a number of other elements, a block containing $\frac{1}{2}$ -in. cubes of 18 different elements was prepared, by placing them in a rectangular mold and pouring an insulating cement between them. Following this, a low melting point

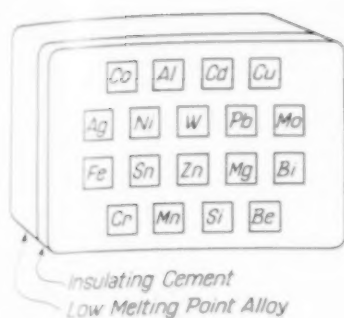


Fig. 3—Test Block, About 2½ by 3 In. in Area, Containing Samples of 18 Metals

alloy was poured into the mold in order that contact could be made to all 18 elements at one time. Finally, the bottom surface of the block was ground down and polished with the result that a flat surface, composed of the polished faces of the 18 cubes surrounded by insulating cement, was obtained. Figure 3 shows the general construction.

A print could then be made from this surface, using high enough current density to assure that some of each element had been driven into the gelatin paper. Subsequent devel-

opment of the paper in a certain reagent would show the colors of the products formed with each of the elements, and in this way any interferences by reason of similarly colored products could be determined. In effect, one print using the sample block would tell as much about color interferences as 18 tests with pieces of the individual elements.

Two such prints are shown in Fig. 4 and 5. Figure 4, which shows a satisfactory print, used the ben-

zoinoxime test for copper. On the original print, the spot in the upper left-hand corner (mirror position for copper as shown in Fig. 3) showed up as a dark green, thus indicating the presence of copper. The dark spots on the right side of this print were not very pronounced, despite their dark tone in the black-and-white reproduction, and were, from top to bottom, a light brown for cobalt, a light pink for silver, and a light orange for iron. Figure 5 shows an unsatisfactory print. In this case, an attempt was made to test for silver using dithizone. The large dark area on the right side of the figure (next to the top), which was violet in color on the original print, showed that a satisfactory test for silver had been obtained. However, a number of the other chemical elements present also printed out strongly, some being in colors very

the two elements occurred at different locations on the surface.

In other cases, it was found that the presence of one element would prevent the formation of a certain compound of another element but, once again, if the two elements occurred at different locations on the surface of the specimen, no difficulty was encountered. An example of such an interference occurred in the detection of iron in an 18-8 stainless steel by means of the well-known ferricyanide test, such a test yielding a negative result. However, if the ferrocyanide test was used, a positive test for iron resulted. In this case, it appears that under the influence of current the chromium present dissolved as the chromate; the chromate then oxidized all of the iron to the ferric state, wherein it could be detected only by the ferrocyanide test. (Separate tests verified the fact that ferrous iron could not be detected in the presence of chromate.)

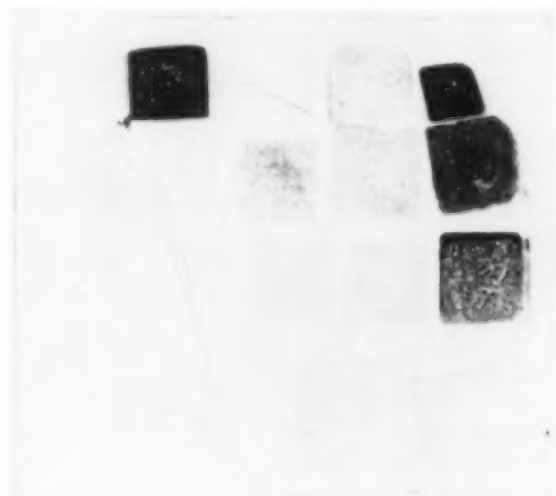


Fig. 4—Satisfactory Print With Test for Copper (Upper Left) Which Shows Characteristic Color and Intensity

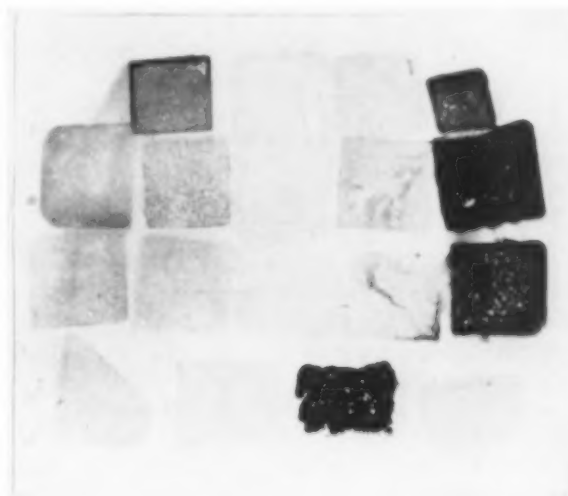


Fig. 5—Unsatisfactory Test for Silver (Next to Top at Right) Gives Similar Colors and Intensities for Iron and Manganese

opment of the paper in a certain reagent would show the colors of the products formed with each of the elements, and in this way any interferences by reason of similarly colored products could be determined. In effect, one print using the sample block would tell as much about color interferences as 18 tests with pieces of the individual elements.

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similar to that produced by the silver.

In general, it was found that the most troublesome interferences occurred when two elements formed compounds of similar colors with a given reagent. If compounds of different colors were formed, it was still found practical to use the reagent in certain cases, provided (a) the compound formed with the interfering element was relatively light in color and intensity, or (b)

Detection of Inclusions

By means of sheet specimens, into which small pieces of certain elements had been pounded to represent inclusions, electrographic tests were made to determine definitely whether the elements forming the artificial inclusions could be detected in the presence of the sheet materials. The results of these tests are shown in Fig. 6 to 9 inclusive.

Tests were made for iron inclu-

sions in copper, lead, zinc, and magnesium using the ferricyanide test (Fig. 6), for copper inclusions in lead, zinc, and magnesium using the benzoinoxime test (Fig. 7), for lead inclusions in copper, zinc, and magnesium using the chromate test (Fig. 8), and for nickel inclusions in copper, lead, zinc, and magnesium using the dimethyl glyoxime test (Fig. 9). As evidenced by the spots which are apparent in the photographs, the inclusions were readily detected in all cases, and the shape and position

material was anodic to the inclusion, and current was necessary to polarize the entire specimen to the open-circuit potential of the more cathodic inclusion before solution of the inclusion could occur.

Using this same type of specimen, the minimum current density required to detect an iron inclusion in a piece of sheet zinc was studied under certain fixed conditions. Using the ferricyanide test as described in Table I and passing the current for 30 sec., a series of prints was made

different minimum current density value would exist. In this connection, the time of current flow will also be important, since a current density might be used which would drive a certain element into the paper but at such a slow rate that a concentration sufficiently high to be detected by a given reagent might not be reached in a given time. However, if the same current were allowed to flow for a sufficiently long time, a high enough concentration would undoubtedly result.

Fig. 6—Iron Inclusions, by Ferricyanide Test

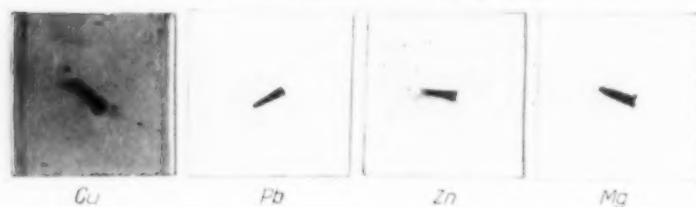


Fig. 7—Copper Inclusions, by Benzoinoxime Test



Fig. 6 to 9—Detection of Artificial Inclusions in Sheets of Material as Noted



Fig. 8—Lead Inclusions, by Chromate Test



Fig. 9—Nickel Inclusions, by Dimethyl Glyoxime Test

of the spot corresponded to the shape and position of the artificial inclusion. In addition, the colors of the spots in the original prints corresponded to the characteristic colors produced by the reagents used. It will be noted that a background color exists in the two engravings showing inclusions in copper, but in the original prints, this was light in color and did not confuse the test in any way. It was also found that the blue ferro-ferricyanide formed in printing iron inclusions in zinc faded rapidly to a dirty gray within a few hours. Such rapid fading did not occur when iron inclusions in the other metals were printed by the same method.

It is apparent that in a few of these tests the inclusion was anodic to the sheet material, and that material from the inclusion would dissolve without the passage of current. However, as previously mentioned, it was found that the electric current produced a more definite and positive test in a shorter time. In most of these tests, however, the sheet

of the piece of zinc sheet containing the artificial iron inclusion using varying current densities. These indicated that under the conditions of test a current density of 0.003 ampere per sq.cm. had to be reached before the inclusion could be detected.

Under similar conditions and using the benzoinoxime test as described in Table I, prints of the piece of magnesium sheet containing the artificial copper inclusion were made. Figure 10 shows that a current density of 0.013 ampere per sq.cm. had to be reached before the inclusion could be detected. It will be noted that a more positive test was obtained as the current density was increased above the minimum.

While the actual current density values are not significant in themselves, they do demonstrate the fact that a minimum current density must be exceeded before a more cathodic material can be electrographically detected in the presence of a more anodic material. If any one of a number of variables were altered, a

Utility of Test

The electrographic method which has been described has been used to good advantage in a number of instances. Certain of the tests conducted with artificial inclusions, which were described previously, have been used to detect and identify actual inclusions whose presence was known but whose identity was either unknown or merely suspected. In particular, small inclusions in some rolled aluminum sheet were detected and found to consist largely of iron.

Porosity Tests—Considerable work has also been done in the determination of the porosity of metallic coatings. By making electrographic prints and testing for iron, the porosity of coatings of tin, aluminum, and zinc on steel has been studied. In these cases, both the presence and the location of the pores could be determined by the blue spots, which were the mirror images of the pores in the metallic coatings.

In the case of a tin coating, the

Fig. 11 (at right) — Contact Print (Above) and Electrographic Print (Below) of Galvanized Iron Known to Be Porous; No Indication Existed on the Former; on the Latter, Many Blue Spots Located the Pores

iron is anodic to the tin in most solutions and could be dissolved by the self-generated current of the iron-tin cell. As a matter of fact, contact prints, in which a piece of paper moistened with a ferrieyanide solution is placed on a specimen of tinplate, have been widely used for such porosity determinations. However, it was found that the electrographic ferrieyanide test was much faster, since satisfactory prints could be made in seconds rather than minutes.

Zinc coatings constitute a different condition, being anodic to the iron in most solutions. As a matter of fact, considerable difficulty has been encountered in obtaining a satisfactory method for determining the porosity of zinc coatings on iron or steel. When the contact method of printing was attempted, the iron did not go into solution, since it was electrochemically protected by the zinc and hence was not detected. It was found that an electrographic method was ideally suited for such a case, since the current polarized the zinc beyond the open-circuit potential of the more cathodic iron, with the result that the iron went into solution and thus could be detected. Figure 11 compares the contact and electrographic prints of a specimen of iron known to have a porous zinc coating. The contact print shown indicates no porosity; however, the electrographic print satisfactorily indicates it, the location of the pores being evident as blue spots on the original print.

Similar conditions were found when testing an aluminum coating on steel. The coating prevented the solution of iron at the pores unless an electrographic method was used. The contact print shown in Fig. 12 indicated no porosity. On the other hand, the electrographic print revealed the true porosity of the coating, the location of the pores being shown by blue spots on the original print.

Some difficulties may be encountered if the coating is either very thick or very thin. If the coating is thick and the pores relatively small and deep, the solution in the

gelatin paper may not contact the material at the base of the pores. Hence, a complete electrical circuit will not exist, with the result that the material at the base of the pores will not be driven into the gelatin. In such cases it is often helpful to place excess solution on the surface of the gelatin paper so that some of it will be forced into the pores when pressure is applied.

In samples where the coating is very thin, the electrographic test may remove sufficient material from the surface of the specimen to lay bare the material under the coating, with the result that pores which did not originally exist will be created. In such cases it is best to pass

the current for as short a time as possible so that very little of the entire surface will be dissolved.

Identification of Alloys — Electrographic tests have also been used to good advantage in the identification of alloys. It was found possible to distinguish commercial aluminum from the aluminum-copper-magnesium alloys (such as the duralumin type alloys 17S-T and 24S-T) by making prints and testing for copper. In another test, two sheets of an aluminum-copper-magnesium alloy having a coating of high purity aluminum (alclad 24S-T), one of which had been heat treated long enough for the

Fig. 12 — Electrographic Methods (Left) Are Better Than Contact Prints for Showing Porosity in Aluminum Coated Steel

copper to diffuse from the base metal to the surface of the high purity coating, were distinguished by making prints and testing for the presence of copper. In still another case, two lots of 18-8 stainless steel, one containing 1% of molybdenum, were separated by printing and testing for molybdenum.

Another experiment was with a group of 13 sheet specimens, identified only by number but among which were known to be nickel, cupro-nickel, 5% and 13%

Fig. 10 — Effect of Current Density in Amperes per Sq.Cm. on the Detection of an Artificial Copper Inclusion in Magnesium Sheet

chromium steels, 18% chromium, 8% nickel stainless steel, and chromel. By printing and testing for iron, chromium, nickel, and copper, the results given in Table II were obtained. A subsequent check of the numbers indicated that the alloys had been identified correctly.

Sensitivity—In addition to the data which have been presented concerning the amounts of the various elements which certain reagents would detect, data have been obtained on the amounts of some of the elements which could not be detected. Tests with a series of aluminum-copper alloys, using a current density of 0.05 ampere per sq.cm. for 30 sec., revealed that the benzoinoxime test would give a posi-

In certain cases, such as those dealing with alloy identification, it would obviously be desirable to tell not only whether or not a certain element existed on the surface of a specimen, but also in what quantity it was present. The tests described have so far proven satisfactory only for qualitative determinations. For instance, 5% and 13% chromium steels could not be distinguished, since a strong test for chromium was produced with both alloys. However, the tests conducted on the binary aluminum-copper alloys indicated that more dense colorations are produced by the benzoinoxime test as the amount of copper present in solid solution in the alloys increased. Hence, it appears entirely possible

of the surface of the specimen under the influence of an applied current and subsequently detecting various elements by means of proper reagents) have therefore been shown to be rapid, simple, inexpensive, and non-destructive, provided attention is paid to a number of the mechanical, electrical, chemical, and electrochemical factors involved. Electrographic tests readily detect certain elements. The method is eminently satisfactory for the location and identification of inclusions, the identification of the type of alloy, and for the determination of porosity in coatings. While the results presented apply mainly to qualitative determinations, some possibilities exist in such a method for quantitative studies.

Table II—Identification of 13 Alloy Sheets by Electrographic Methods

UNKNOWN NUMBER	TESTED FOR				ELECTROGRAPHIC PREDICTION	ALLOY SUBSEQUENTLY IDENTIFIED AS
	Fe (a)	Cr (b)	Ni (c)	Cu (d)		
1	Positive	Positive	Positive	Negative	Fe-Cr-Ni Alloy	18-8 stainless steel
2	Positive	Positive	Positive	Negative	Fe-Cr-Ni Alloy	18-8 stainless steel
3	Positive	Positive	Positive	Negative	Fe-Cr-Ni Alloy	18-8 stainless steel
4	Positive	Positive	Negative	Negative	Fe-Cr Alloy	13% Cr steel
5	Negative	Negative	Positive	Positive	Cu-Ni Alloy	Cupro-nickel
6	Negative	Negative	Positive	Negative	Nickel	Nickel
7	Positive	Positive	Negative	Negative	Fe-Cr Alloy	13% Cr steel
8	Negative	Negative	Positive	Positive	Cu-Ni Alloy	Cupro-nickel
9	Negative	Negative	Positive	Positive	Cu-Ni Alloy	Cupro-nickel
10	Positive	Positive	Positive	Negative	Fe-Cr-Ni Alloy	18-8 stainless steel
11	Positive	Positive	Positive	Negative	Fe-Cr-Ni Alloy	18-8 stainless steel
12	Positive	Positive	Negative	Negative	Fe-Cr Alloy	5% Cr steel
13	Negative	Positive	Positive	Negative	Cr-Ni Alloy	Chromel A (80% Ni, 20% Cr)

(a) Thiocyanate test

(b) Peroxide test

(c) Dimethyl glyoxime test

(d) Benzoinoxime test

tive test for copper with those alloys containing more than 2% copper, but below this amount the results were either consistently negative or uncertain. It was found that, under the same conditions, the ferricyanide test would not detect 1% of iron in a binary aluminum-iron alloy, the peroxide test would not detect 0.25% of chromium in an aluminum-magnesium-chromium alloy (52S), the iodide test would not detect 0.5% of lead or 0.5% of bismuth in an aluminum-copper-lead-bismuth alloy (11S-T), nor would the chromate test detect the 0.5% of lead in this same alloy.

Discussion and Summary

Up to this point in our investigation, emphasis has been placed on obtaining satisfactory tests for the detection of a number of elements.

that the electrographic method might be used for quantitative determinations provided the amount of current, time of printing, and other factors were standardized.

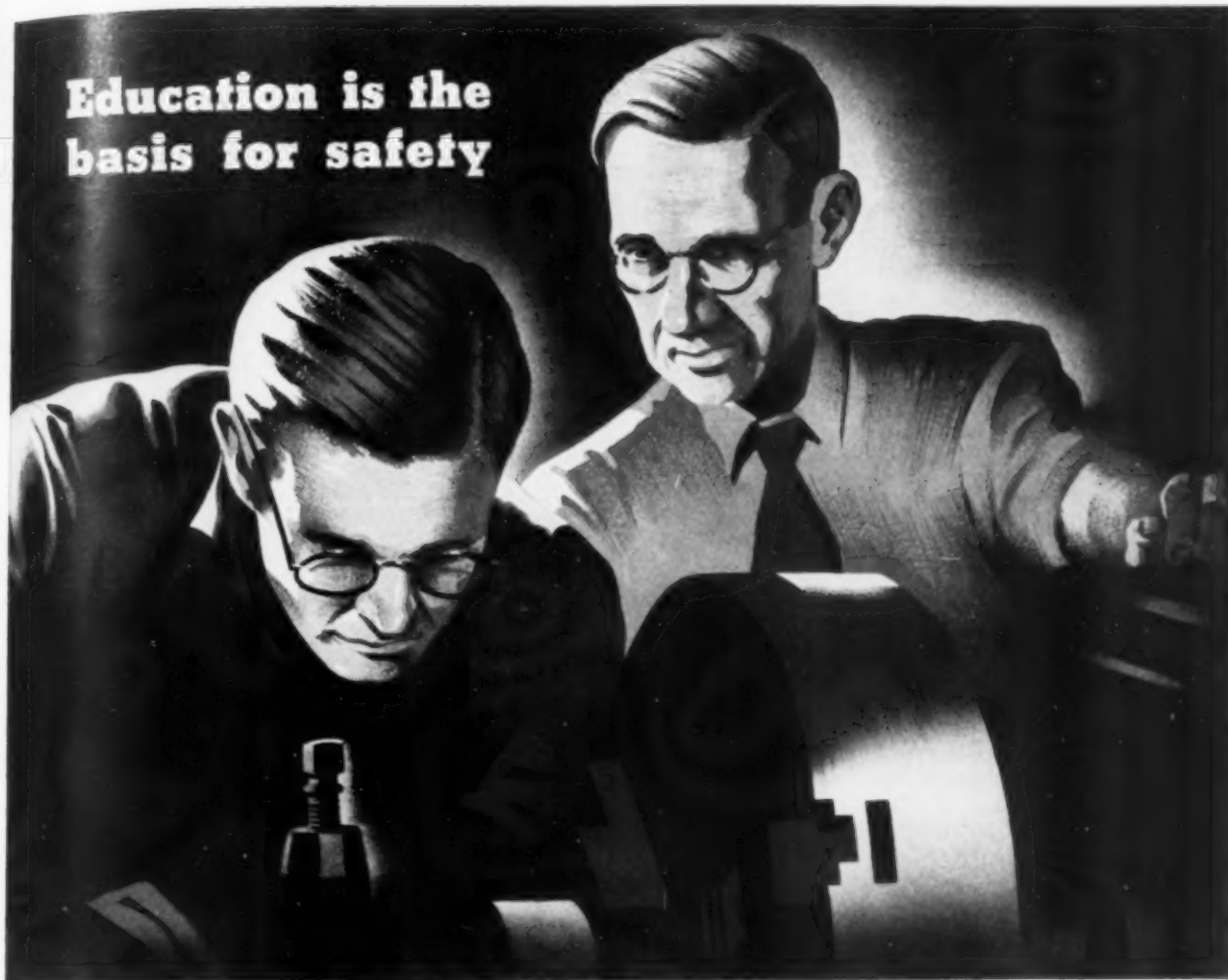
Naturally, the degree of dispersion of the minor constituent will play an important part in the ability of a certain electrographic test to detect it. If the constituent is in solid solution or is finely dispersed, a given test may not detect it because the concentration at any one location is too low. However, if it is all located in a few regions (as in inclusions) the local concentration will be high and hence the electrographic test will be satisfactory.

Electrographic methods for analyzing the surface of metal specimens (by dissolving a small amount

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Nevertheless, the large increase in labor personnel due to war needs, plus the influx of inexperienced men, have resulted in a substantial increase in lost time accidents.

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Personals

C. H. Mathewson ☉, chairman of the department of metallurgy at Yale University, has been elected president of the American Institute of Mining and Metallurgical Engineers. Charles H. Herty, Jr. ☉, assistant to vice-president, Bethlehem Steel Co., is director.

P. H. Brotzman ☉ has left the American Fork & Hoe Co., where he was assistant metallurgist, and has accepted a position as chief metallurgist, Parker Appliance Co., Cleveland.

J. E. von Maur ☉ has been appointed representative of American Gas Furnace Co. of Elizabeth, N. J., throughout the State of Ohio, with offices in Columbus and Cleveland.

Newly elected officers of the International Acetylene Association: Ellsworth L. Mills, vice-president, Bastian-Blessing Co., president; Glenn O. Carter, consulting engineer, The Linde Air Products Co., vice-president; Herbert F. Reinhard, re-elected secretary; and Philip Kearny, president of K-G Welding and Cutting Co., treasurer.

Walter R. Meyer ☉, formerly editor of *Metal Finishing and Plating and Finishing Guidebook*, has become technical director of The Enthone Co., New Haven, Conn.

H. L. Harvill ☉ has announced his re-entrance in the field of aircraft die castings as head of his own organization, the H. L. Harvill Co., Los Angeles. S. I. Gleason ☉ is metallurgist for the new company.

Promoted by Allegheny Ludlum Steel Corp.: W. E. Griffiths ☉, formerly manager of the product development department, to assistant manager of sales, flat rolled products.

Victor Brown ☉, formerly metallurgical contact representative, Republic Steel Corp., South Chicago plant, has been appointed metallurgist for Kropp Forge Co., Chicago.

Gale S. Hanks ☉ has resigned as assistant metallurgist at Frankford Arsenal, Philadelphia, to accept a position as senior engineer for Remington Arms Co., Inc., at the Denver Ordnance Plant, Denver, Colo.

Appointed by War Production Board: Edwin H. Brown, engineering vice-president of the Allis-Chalmers Mfg. Co., as assistant chief of the Iron and Steel Branch in charge of the plant facilities section. During his absence, Forrest Nagler ☉, chief mechanical engineer, will be in charge of the Allis-Chalmers engineering and development department.

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December, 1942; Page 1079

Personals

Elected president of National Bronze & Aluminum Foundry Co., Cleveland: **John L. Schmeller** Ⓔ, formerly executive vice-president.

Charles R. Foreman Ⓔ, formerly in the metallurgical department of Olds Motor Works at

Lansing, Mich., is now a member of the metallurgical department, Park Chemical Co., Detroit. **Earl H. Seelbach** Ⓔ represents the company in northern New York from Syracuse to Buffalo, including Ontario, Canada.

Oscar Sander Ⓔ, formerly with Emerson Electric Co., St. Louis, is now supervisor of heat treating, Gear Grinding Machine Co., Detroit.

E. J. Hergenroether Ⓔ, formerly with the Conservation Division of the War Production Board, is now consultant, Metallurgical and Specifications Section, Iron and Steel Branch.

D. F. Armiento Ⓔ, formerly assistant metallurgist, research laboratory, Carnegie-Illinois Steel Corp., is now with Frankford Arsenal, Philadelphia, as associate metallurgist.

John Howe Hall Ⓔ has given up his consulting practice and is now with General Steel Castings Corp., Eddystone, Pa., as metallurgist.

Anson B. Albree, chairman of New Haven Chapter Ⓔ War Products Advisory Committee, and formerly purchasing agent and metallurgist, Bridgeport Grinding Machine Co., is now associated with the A. F. Holden Co., West Haven, Conn., assigned to research and development of new products.

John R. Ramson, Jr. Ⓔ, formerly apprentice engineer, Carnegie-Illinois Steel Corp., Homestead Works, is now engineer with the Glenn L. Martin Co., Baltimore.

Paul P. Bauernschmid Ⓔ has left his position as chief designer with the Chandler-Evans Corp., South Meriden, Conn., and is now design engineer for the Waterbury Tool Division of Vickers, Inc., Waterbury, Conn.

George L. Mitsch Ⓔ, formerly with Midvale Co., Philadelphia, is now with Eastern Aircraft Trenton Division of General Motors Corp., working on special assignments particularly in the conservation of critical materials.

Cleaveland F. Colburn Ⓔ has terminated his work as foundry engineer for Goulds Pumps, Seneca Falls, N. Y., to become plant metallurgist at the Lawrence Engineering & Research Corp., Linden, N. J.



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Personals

Robert H. McKean ⚙, formerly chemist and metallurgist, National Malleable and Steel Castings Co., Sharon, Pa., is now assistant metallurgist at Frankford Arsenal, Philadelphia.

Charles D. Young ⚙, formerly district manager of Metal & Ther-

mit Corp.'s Chicago office, has been appointed sales manager of the Welding Division of the corporation in New York.

Donald W. White, Jr. ⚙, formerly associated with the metallurgical department of Crucible Steel Co. of America, Sanderson Works, is now employed as a metallurgist at Sylvania Electric Products, Inc., Radio Tube Division, Emporium, Pa.

Welton J. Crook, past chairman of the Golden Gate Chapter ⚙, professor of metallurgy, on leave, at Stanford University, Calif., has been promoted from lieutenant colonel to colonel, Ordnance Department, stationed at Rock Island Arsenal, assigned as technical officer and officer in charge, Steel Foundry Division.

L. G. Vande Bogart of Crane Co. has been elected chairman of the Corrosion Division of the Electrochemical Society; **H. H. Uhlig** ⚙ of General Electric Co. has been elected vice-chairman; and **R. H. Brown**, Metallurgical Division, Aluminum Research Laboratories, has been elected secretary-treasurer.

J. Earl Harrington ⚙ has severed his connection with Greeley & Hansen, consulting engineers, Chicago, to accept a position with the War Department, Office of the Chief of Ordnance, Security and Safety Branch, as chief of the High Explosives Manufacturing and Raw Materials Unit, Chicago.

Herbert V. Thaden ⚙ has organized the Thaden Engineering Co. in Roanoke, Va., to service various woodworking and furniture plants.

Wallace W. Beaver ⚙ has resigned as metallurgist, Federal Machine and Welder Co., Warren, Ohio, to become research engineer, Battelle Memorial Institute, Columbus, Ohio.

Ray P. Dunn ⚙, formerly in charge of metallurgical inspection at Emerson Electric Mfg. Co., Turret Division, St. Louis, Mo., is now metallurgist with Doehler Die Casting Co., Toledo plant.

William R. McCormick ⚙, formerly metallurgical engineer, National Tube Co., Ellwood Works, is now assistant chief metallurgist, Tubular Alloy Steel Corp., Gary, Ind.



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☐ THERMOCOUPLE ACCESSORIES
☐ THERMOCOUPLE ALLOY
☐ THERMOMETERS
☐ VALVES
☐ WIRE (Thermocouple)
☐ X-RAY SERVICE

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Personals

Col. Glen F. Jenks ☉ has retired from active service with the U.S. Army and accepted a position as consulting engineer, Taylor-Winfield Corp., Warren, Ohio.

W. C. Heaslip ☉, formerly superintendent of the shell forg-

ing plant of General Railway Signal Co., Rochester, N. Y., is now with Rheems Mfg. Co. as superintendent of the Birmingham, Ala., plant.

D. A. Wigton ☉ has left his position as metallurgist with National Tube Co., Lorain, Ohio, to become metallurgist in the aluminum foundry of the Dallas, Texas, branch of the Willard Storage Battery Co.

Glen C. Ware ☉ has resigned as assistant professor of chemistry at Oregon State College to become associate chemist with the U.S. Bureau of Mines Inter-mountain Station at Salt Lake City, Utah.

S. Proctor Rodgers ☉ has left the Consolidated Gas, Electric Light & Power Co. of Baltimore and is now chief of the Fuel Section of the Army and Navy Munitions Board in Washington.

G. R. Fitterer ☉, of the department of metallurgy of University of Pittsburgh, has been appointed director of research of the newly formed Acid Open-Hearth Research Association and J. W. Linhart is research metallurgist. H. G. Grim is chairman, F. H. Allison ☉ is vice-chairman, F. C. T. Daniels ☉ is secretary, and R. C. Heaslett ☉ is treasurer. The executive committee consists of George S. Baldwin ☉, H. E. Dowie ☉, Walter H. White ☉, J. S. Zahn, J. L. Nichols, E. H. Harder, E. H. Mebs ☉, W. E. Harvey ☉, and Herman P. Rassbach ☉.

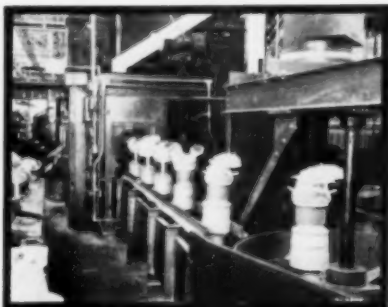
Orien Simmons ☉, formerly instructor in chemical engineering, Rose Polytechnic Institute, Terre Haute, Ind., is now research engineer, Battelle Memorial Institute, Columbus, Ohio.

Sydney J. Waters ☉, formerly research project engineer at Northrop Aircraft, Inc., is now consultant, aircraft division, Willys Overland Motors, Toledo, Ohio.

Robert Rennie ☉ has left the chemical and metallurgical department of the Westinghouse Electric & Mfg. Co. at Bloomfield, N. J., and is now metallurgist with the Vascoloy-Ramet Corp., North Chicago, Ill.

Robert A. Smith ☉, formerly metallurgist with Sears, Roebuck & Co., Chicago, is now head of the metallographic and heat treating laboratories at Dodge-Chicago plant of Chrysler Corp.

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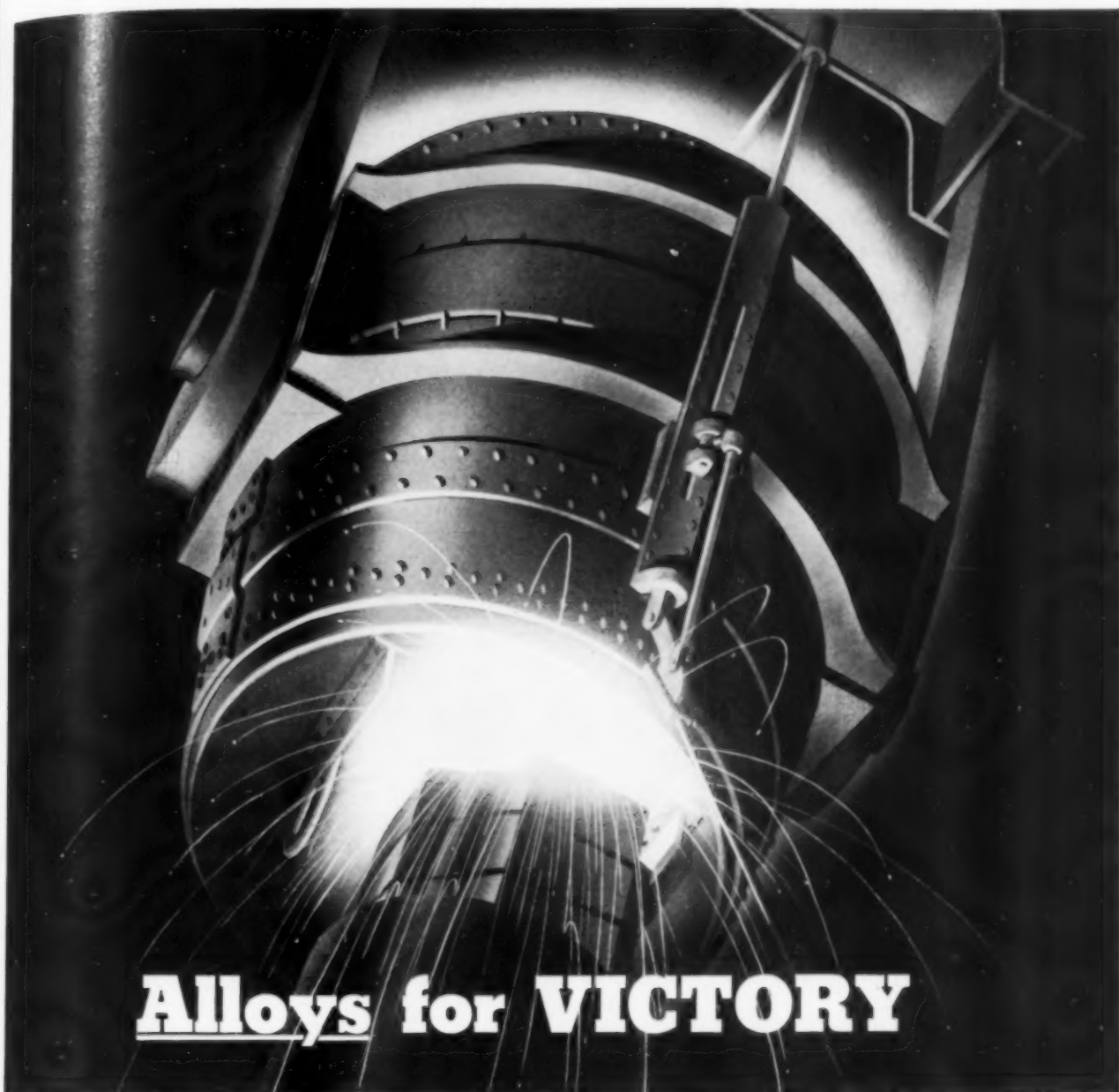
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Personals

James O. Johnson Ⓔ, formerly chief product engineer of Aircraft-Marine Products, Inc., Elizabeth, N. J., has been made assistant merchandise manager.

Howard A. Smith Ⓔ, formerly with Universal-Cyclops Steel Corp., Bridgeville, Pa., is now

chief metallurgist for Tubular Alloy Steel Corp., Gary, Ind.

First Lieut. William F. Silsby Ⓔ, formerly of Pittsburgh, is now in the Department Engineer Office, Fort Shafter, Territory of Hawaii.

Austin Hiller Ⓔ, formerly metallurgical engineer, Planning and Utilities Division, Pittsburgh Ordnance District, is now process

development engineer, Remington Arms Co., Inc., Bridgeport, Conn.

Lloyd T. Pearce Ⓔ, formerly metallurgist, Allis-Chalmers Mfg. Co., Laporte, Ind., is now metallurgist, Oldsmobile Janesville Division, Janesville, Wis.

Robert A. McCloud Ⓔ, formerly with Ford Motor Co., is now process engineer, Development and Engineering Division, Henry J. Kaiser Co., Oakland, Calif.

Roy Erwin Swift Ⓔ, formerly with the department of mechanical engineering of Louisiana State University, is now instructor of metallurgy for the School of Mines, University of Alaska.

A. G. Bucklin Ⓔ, formerly metallurgical engineer, research laboratory, Crane Co., Chicago, is now research assistant in metallurgy, Massachusetts Institute of Technology.

Raymond L. Costa Ⓔ has left his position as tungsten metallurgist with RCA to join the research staff of the Mutual Chemical Co. of America at its Baltimore plant.

William E. Ashe Ⓔ, formerly assistant superintendent of the fine wire mill, Wickwire-Spencer Steel Co., Buffalo, is now associated with Worcester Stamp Metal Co., Worcester, Mass.

James H. Dodge, chairman, Toledo Group of Detroit Chapter Ⓔ, district manager for Latrobe Electric Steel Co. in Toledo, has been transferred to Hartford, Conn., to take charge of the New England territory.

Donald B. Graves Ⓔ is now employed by the Federated Metals Co. at the Central Research Laboratory of American Smelting & Refining Co., Barber, N. J., as assistant metallurgist.

Transferred by Republic Steel Corp.: **R. W. Farley** Ⓔ, from field engineer, Lubbock, Texas, to metallurgical department, Cleveland.



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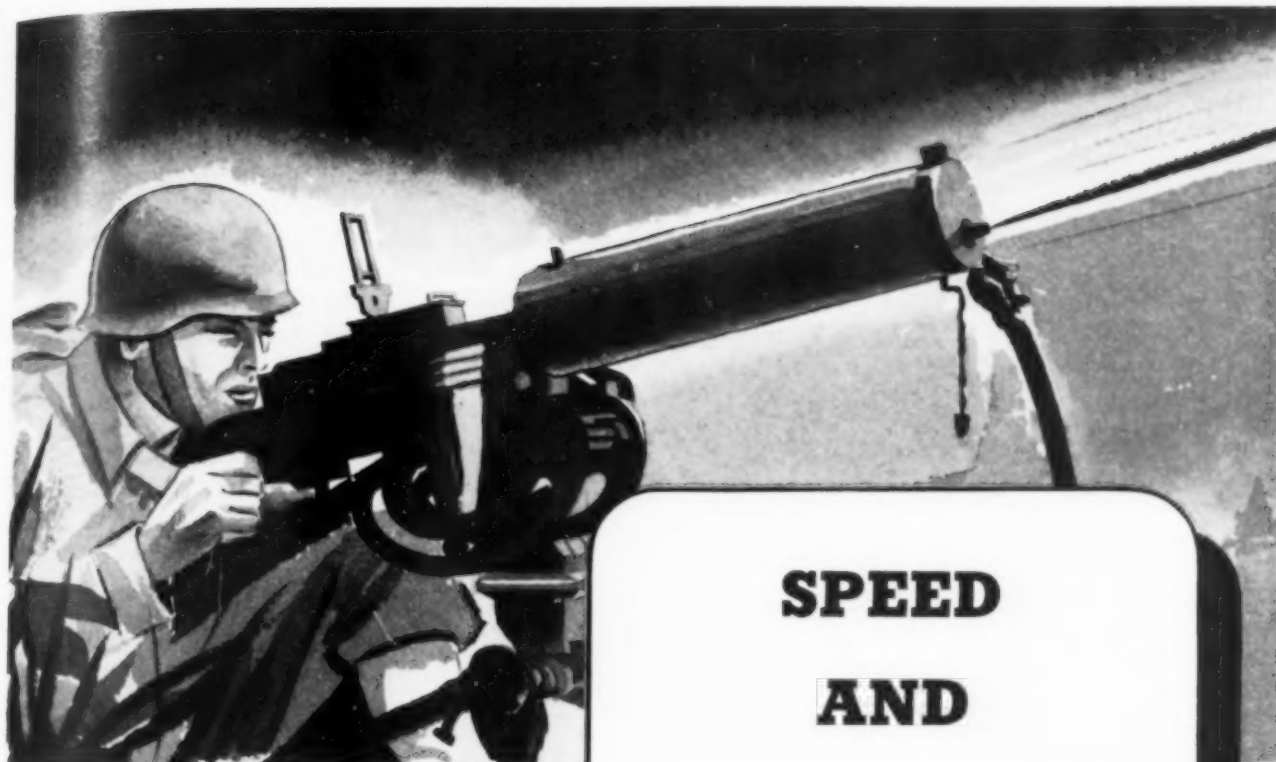
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Precision in Creep Testing*

By J. A. Fellows, Earnshaw Cook and H. S. Avery

INCREASED use of heat resistant alloys has required critical studies of the basic causes of variations in service, and techniques of investigation have been refined and new test methods and instruments created. For

example, the creep test laboratory at American Brake Shoe and Foundry Co. utilizes 1000-hr. tests in the range of 1200 to 2200° F., with applied stress ranging at will from 50 to 50,000 psi. In the furnaces a maxi-

mum temperature gradient of $\pm 1^\circ$ F. is maintained over a 4-in. gage length; uniformity is maintained by a judicious use of shunts in the heating circuits.

Earth temperature is used as the reference point for control, since extension leads encased in rubber-insulated, lead-sheathed cables are sunk 32 ft. underground. The total change of the cold-junction temperature during the year is within 1.5° F. as measured by an iron-constantan thermocouple. It is interesting to note that this temperature lags approximately six months behind that at the surface.

Effect of Cyclic Temperature Variations Upon Creep Rate—Temperature control when testing austenitic alloys deserves special emphasis, for it was discovered that a variation of $\pm 10^\circ$ F. in a 7-min. cycle increases the creep rate six-fold.

In regard to the thermocouples the chief difficulty is encountered in maintaining constant calibration. Oxides of chromium and iron volatilized from the test bar condense upon the thermocouple leads and cause serious contamination. Where sharp thermal gradients exist, errors as high as 27° F. have been detected. To avoid this situation, gas-tight alundum protection tubing has been secured. Thermocouples are spot-welded to the specimen to establish good thermal contact. This has no detectable effect upon the calibration.

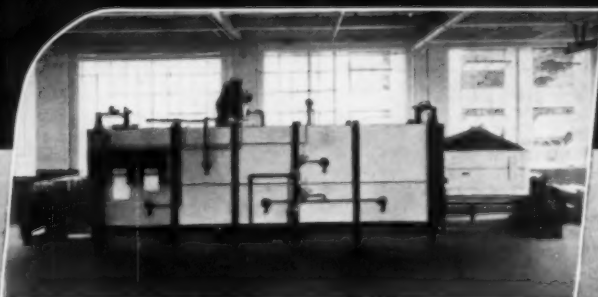
Elongation is measured by means of a telescope sighted on 90% Pt, 10% Rh extensometers spot-welded to each side of the gage length. The telescope is similar to the design adopted by the creep laboratory of the U. S. Steel Corp., with a modified mount, calibrated with a stage micrometer. Cross-hair settings upon the extensometers permit a

(Continued on page 1090)

*Abstracted from Technical Publication No. 1443, American Institute of Mining and Metallurgical Engineers, 1942.

Heat-Treating

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The substitution of steel for brass in the manufacture of cartridge and shell cases required considerable research in the selection of a suitable deep drawing steel having the desired physical properties.

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Creep Test

(Continued from page 1088)

daily determination of flow in the specimen. Calculation of the human error in observations, of the mechanical uncertainty of the filar eyepiece, and of the thermal expansion of the coupon for 1° F. deviation, indicates a

possible variation (when none of these factors are mutually compensating) of ± 0.000026 in. per in., or approximately 2.5 times the precision of plotting.

Evaluation of Results: Experiments have proved that stress-strain-rupture tests can serve as abbreviated creep tests. For such work the above-described equipment is used with certain modifications. A gear mechanism adjusts the lower grip anchorage

to prevent the loading beam from reaching its stop before failure occurs. The gage length is limited to 2 in. The furnace differs only in the design of the heating element to compensate for the greater heat flow through the heavy grips. The calibration furnace contains a zone of equivalent thermal gradient. Time to failure is recorded by a clock set in motion the instant load is applied. Elongation is measured by three means: The first is a selected spot check with the telescope sighted on extensometers, as in the creep test. Both the other two methods use the motion of the upper grip.

The curve for fracture-time versus stress is extrapolated to indicate its possible use in forecasting *maximum* attainable service life at that temperature.

The need for a quantitative evaluation of the influence of ferrite in the microstructure on the creep strength of the specimen was soon realized. For this purpose an instrument was secured in 1936 capable of determining permeabilities from 1,000 to 300 ($H = 24$), and so estimating the amount of ferrite in the specimen at any time during test. The smallest interval that can be measured, reproducibly, is 0.003. Tests indicate that increased permeability is accompanied by increased flow and decreased strength.

In conclusion, it is again emphasized that an adequate approach to accurate and comparable creep testing of nickel-chromium alloys requires meticulous experimental techniques with special attention to (a) precision of elongation measurements well within over-all experimental error; (b) precision of thermocouple calibration and special precautions in temperature measurements; (c) precision of temperature control within a maximum cycle of $\pm 0.5^\circ$ F. and a desirable maximum variation about the control point of $\pm 1.5^\circ$ F. ⊙



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give you a skill which can mean *worthwhile savings* to you.

These modern plants are keeping pace with growing demands . . . are expanding plant facilities . . . are installing new, modern furnaces and equipment . . . are all set to step in and help you maintain schedules. Often there is a simple way to do the job . . . a method which lowers cost . . . a system which does away with costly production bottlenecks. It is the business of the Commercial Heat Treater to know that "short cut".

If you are wondering today how to meet heat treating problems, pick out a nearby Commercial Heat Treater . . . *from the list below* . . . and let him add his production facilities and skill to your operation. *It will PAY!*

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5418 LAKESIDE AVE. - HENDERSON 9100

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Commercial Steel Treating Corporation
6100 TIREMAN AVE. - TYLER 6-6086

Commonwealth Industries
322 COMMONWEALTH AVE. - MADISON 0573

ELIZABETH, N. J.

American Metal Treatment Company
ELIZABETH 2-2121

MILWAUKEE

Thurner Heat Treating Co.
809 W. NATIONAL AVE. - MITCHELL 6360

NEWARK, N. J.

Foster Steel Treating Co.
220-222 CLIFFORD ST. - MARKET 3-6400

NEW YORK

Fred Heinzelman & Sons, Inc.
154 SPRING STREET - WALKER 5-2666

Alfred Heller Heat Treating Co.
379-391 PEARL ST. - BECKMAN 3-4531-5

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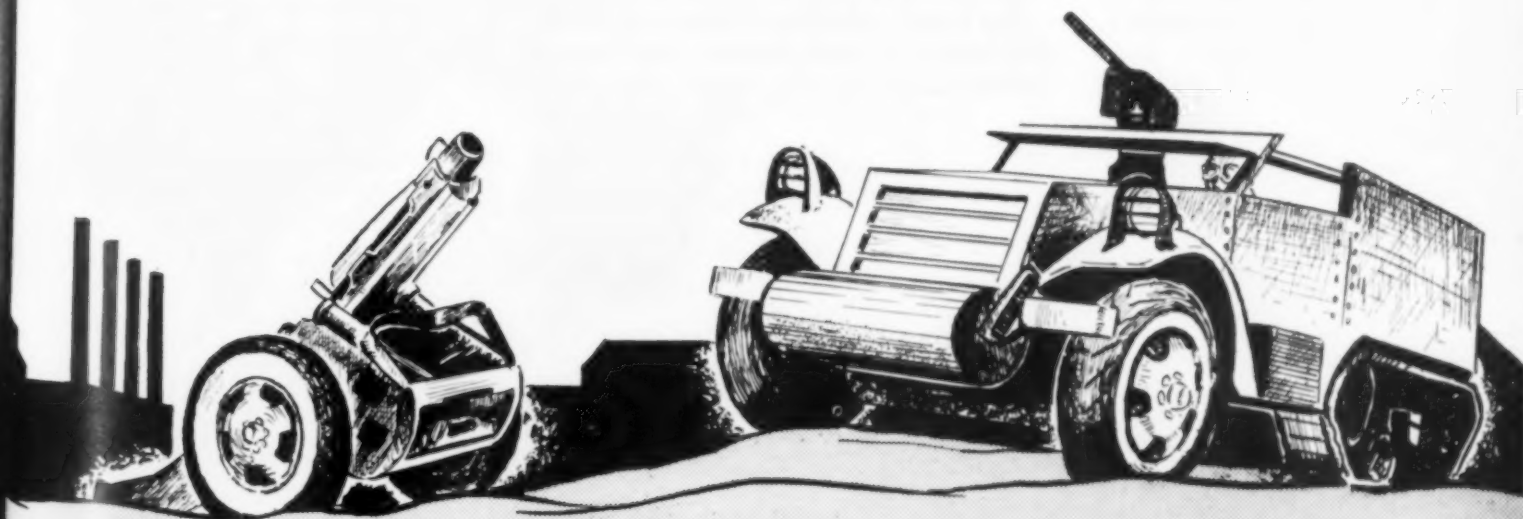
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Massachusetts Steel Treating Corp.
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England Saves Tin*

ENORMOUSLY increased demand for non-ferrous metals for war purposes and restriction of supplies make it necessary for the most stringent economies. It is no longer possible to maintain peacetime standards of perfection and it is

the duty of all to insure that the quality of the material employed is never higher than absolutely necessary. The need for economy applies to all non-ferrous metals.

Approximately one-third of all the tin used in this country goes into copper alloys. It is essential, therefore, that tin-bearing alloys should never be used if a tin-free material can be employed, and that, where this is not possible, the tin content

should be reduced to a minimum. To assist users to meet this urgent need, a new range of standards for copper alloy ingots and castings has been issued by the British Standards Institution, which immediately supersedes certain existing standards.

The following general considerations should be remembered:

(a) Never use a non-ferrous metal or alloy unless it is certain that there is no substitute available which is more plentiful.

(b) Where a non-ferrous material is necessary, use the least possible weight of the lowest possible grade.

(c) Make sure that all scrap is kept clean and free from contamination; use the highest possible proportion of scrap, but never of a higher grade than is absolutely necessary.

(d) Do not hoard scrap; if you cannot use it for approved purposes, sell it for prompt use.

(e) If you are accumulating works residues such as skimmings, casters' ashes and sweepings and cannot re-use them in your own products, get official advice as to where it can most usefully be directed.

In regard to the new British standard alloys, the following points are of importance:

(1) Practically all requirements for cast gun metals and brasses can be met from the following alloys: For very special applications, 88-10-2 (88% copper, 10% tin, 2% zinc) and 88-8-4; for high-grade work, 86% copper, 7% tin, 5% zinc, 2% lead; for general work, but only where a tin-bearing alloy is essential, 85-5-5-5 Cu-Sn-Zn-Pb; for general work in place of tin-bearing alloys, type A brass; for all work where a copper alloy is not required to have any special properties, type B brass.

(Continued on page 1096)

*From "Economy in the Use of Non-Ferrous Metals", official statement of British Non-Ferrous Metals Control, *The Engineer*, Sept. 18, 1942, p. 235.

OF SPECIAL INTEREST TO ALL TOOL SUPERVISORS

If you are having difficulty getting satisfactory results with Moly tool bits, we may be able to help you.

The TUFF-HARD Moly bits (heat treated by the patented TUFF-HARD process) are recognized as superior all-purpose tools and have definitely established themselves as THE tool bit to use on "tough jobs", especially those involving interrupted cuts and impact applications on steel harder to machine than SAE 1045 annealed.

Right today, they are setting records machining tank turrets, flame-cut armor plate, gun housings, 40 mm. shells, etc., etc., in some of America's largest and best known plants. In many instances, they replaced tungsten-cobalt high-speed steels!

To date, insufficient steel supplies have prevented us from taking on new customers. Now, with the purpose of helping speed war production to a greater degree, we are prepared to make the following offer:

Upon receipt of data concerning your most difficult machining operation on which you are using Moly steel (size of bit, material being cut, feed, speed, etc.), we will furnish up to six TUFF-HARD Moly bits for testing purposes together with special testing suggestions and engineering data. These will be supplied on memorandum charge with the bits returnable for full credit if they do not demonstrate unquestionable superiority. Minimum priority rating acceptable—A-1-A.

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TUFF-HARD

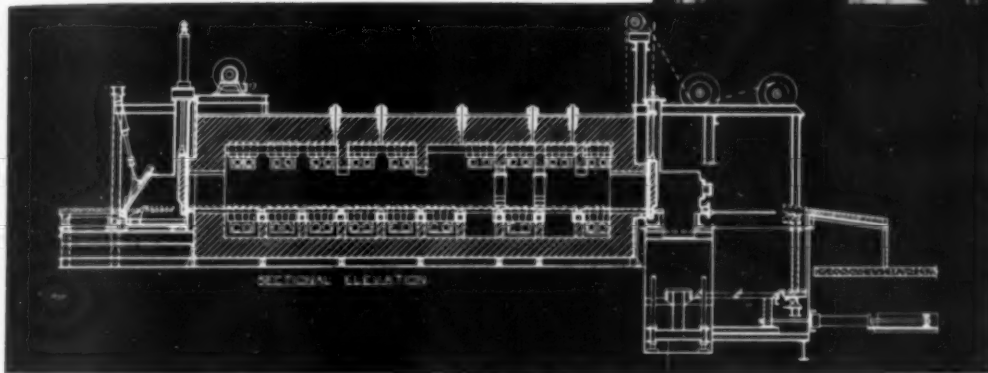


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A WAR PRODUCTION ESSENTIAL . . .

TODAY heat treating processes require even greater uniformity and quality control than ever before . . . for close tolerances are essentials in the production of many war materials.

Controlled Atmosphere . . . which Holcroft helped pioneer and develop in heat treating furnaces . . . is the answer to these severe requirements.

Today Holcroft produces six general classes of furnaces using *Controlled Atmosphere*. Namely:

1. Clean or bright annealing furnaces.
2. Short cycle malleable annealing furnaces.
3. Clean hardening, non-carburizing furnaces.
4. Light case carburizing furnaces.
5. Carbo-Nitriding furnaces.
6. Deep case carburizing furnaces.

Whether it is gas, oil or electric heat, Holcroft has the answer . . . and stands ready with experienced assistance to help solve heat treating problems.

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6545 Epworth Boulevard, Detroit.
In Chicago—C. H. Martin, 1355 Peoples Gas Bldg.
In Canada—Walker Metal Products, Ltd., Walkerville, Ont.

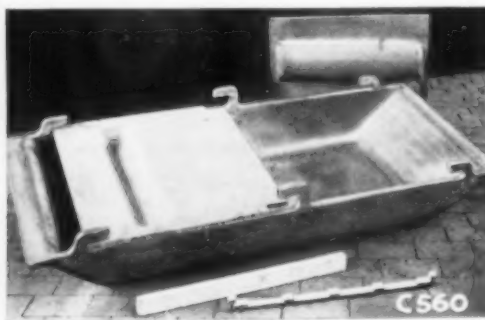
These 8 "Pointers" Will Help You Get Maximum Service from Lead and Cyanide Pots

1. Avoid direct contact of flame with pot.
2. Remove sludge from bottom of pot daily or as often as practicable. The life of the pot is in direct proportion to the frequency with which it is cleaned out.
3. Furnace atmosphere around the pot should be pyrometrically controlled to prevent pot exterior from exceeding 2000°F. Amsco Alloy begins to slowly oxidize above this temperature.
4. Do not exceed thermal capacity of bath. Pyrometer inside of pot should be carefully watched because an excessive drop in temperature indicates cold material is being charged in excessive quantities and too frequently. High rates of firing are then required to bring up the temperature, which reacts unfavorably on the pot exterior.
5. Baths should be brought to operating temperature as slowly as possible.
6. Use an effective seal between pot rim and furnace rim to prevent spillage or "creeping" of salts. Combustion products of all heat treating salts are highly corrosive and cause rapid deterioration of pots and furnace linings.

Inspect frequently to make certain salts are not reaching outside of pots.

7. When furnace is not in operation, such as overnight, keep burners on enough to prevent solidification of bath. Extended pot life and savings in time required to bring both back to operating temperature will more than offset cost of fuel.
8. Where firing conditions make impingement of flame on pot unavoidable, it is advisable to turn pot occasionally, so as to expose all sides equally to the higher temperature at the point of impingement.

Typical units are shown: R-433, a 20"x20" cyanide pot of Amsco Alloy grade F-1. C-560, a lead pan of grade F-10. Beside pots, carburizing containers of unit and sectionalized design, trays, muffles, retorts, conveyor chain and furnace parts are available of laboratory controlled, X-ray checked, Amsco Alloy. Amsco metallurgists and engineers have helped, in an advisory capacity, to convert the heat treating equipment of many plants to war production. Send for Bulletin 1041-A.



Amsco
AMERICAN MANGANESE STEEL DIVISION
OF THE AMERICAN BRAKE SHOE & FOUNDRY CO.
Chicago Heights, Illinois

FOUNDRIES AT CHICAGO HEIGHTS, ILL.; NEW CASTLE, DEL.; DENVER, COLO.; OAKLAND, CALIF.; LOS ANGELES, CALIF.; ST. LOUIS, MO.
OFFICES IN PRINCIPAL CITIES

Genuine Manganese Steel, "The Toughest Steel Known"
Chromium-Nickel Alloy Castings for heat and corrosion
Power Shovel Dippers, Dredge and Industrial Pumps
Welding Materials for reclamation and hard-surfacing

England Saves Tin

(Continued from page 1094)

(2) The most efficient use of scrap is essential. The grade of scrap should never be higher than the alloy in which it is to be incorporated, unless to counterbalance the use of a still lower grade of material.

(3) When sufficient supplies of scrap are not available to meet demands, virgin material must be provided. As far as possible, it must be used only in the highest grades of alloy (88-10-2, 88-8-4 or phosphor bronze). Virgin metal or material of comparable quality should preferably be employed in castings of alloys made direct in one melting stage. This releases ingot-making capacity for lower grade alloys from mixed scrap of indefinite composition, which requires to be melted in bulk under properly controlled conditions.

(4) British Standard 1025-6 for type A casting brass has been designed to take care of the lower grades of scrap unsuitable for the better qualities of wrought products. The aluminum content has been kept low to insure a good casting material. Elements other than copper and zinc are looked upon as impurities and limits merely cover such quantities as may be present as impurities in the scrap from which the brass is produced.

(5) British Standard 1027-8 for type B brass has been designed to take care of the lowest grades of scrap only—principally material more highly contaminated with aluminum, which is allowed as an impurity up to 0.25%. Allowable elements other than copper and zinc are regarded as impurities only and must never be added intentionally. If contamination and mixing of scrap is avoided, very little material should be available for type B brass.

Contributors to This Issue

How a MINING ENGINEER out of Minnesota and Alaska happened to gravitate to Burbank, Cal., and end up studying the metallurgy of spot-welds in an aircraft plant is a question that remains unanswered in the brief biographical notes submitted by **J. R. Heising**, co-author with **E. H. Burkart** of the leading article in this issue. Suffice it to say he has been metallurgical research engineer for Lockheed Aircraft Corp. for the past three years. He was previously associated as engineer with Pickands-Mather & Co., Scranton Iron Mine, Hibbing, Minn., and engineer and assayer for Alaska-Pacific Consolidated Mining Co. at Independence Mine, Anchorage, Alaska. Mr. Heising was a member of the class of 1937, School of Mines and Metallurgy, University of Minnesota.

Co-author **E. H. Burkart** has been with Lockheed for 2½ years, latterly as supervisor of sheet metal forming and metallurgical research and development work in the critical materials substitution program. He is a product of Massachusetts Institute of Technology (B.S. and M.S., '23 and '24) and has had 13 years experience with American Steel Foundries, starting as a special apprentice and ending as assistant research director.

W. O. Philbrook's Bachelor of Science degree was accompanied by honors in chemistry and a Phi Beta Kappa key when he was graduated from University of Chicago in 1934. He immediately went to work at the Wisconsin Steel Works of International Harvester Co. as test carrier in the

laboratory, progressing through various routine analysis jobs to a research assignment studying the chemistry of the basic openhearth process. The spot test for chromium described on page 1035 is one of the results of this research work.



REGINALD S. DEAN



CARL A. ZAPFFE



W. O. PHILBROOK



E. H. BURKART



J. R. HEISING

Intensifiers

(Continued from page 1063)

which cannot be exceeded without marked detrimental effects, principally hot shortness. Unfortunately, their optimum concentration is not far removed from the allowable maximum concen-

tration, and in using such alloys, any unforeseen excessive oxidation may mean partial or entire loss of benefit, since no "insurance" can be carried in the form of an excess of special alloy.

In the production of fine-grained steel, the steel maker often adds small amounts of a strong deoxidizer in the mold to the last few ingots poured on a heat, to prevent loss of grain control, or coarsening of the

grain on such ingots, caused by contact of the last steel in the ladle with the oxidizing slag floating on the surface of the steel in the ladle. This practice is usually beneficial when the special alloying agents are used, since contact with the slag in the ladle may burn up or oxidize the strong deoxidizer protecting them and thus allow loss of the alloy when subsequently exposed to the air during teeming.

Once the treated steel is in the molds, it is handled exactly the same as any steel of the same base composition, untreated, with one possible exception. Steel of a certain base composition may be free from the hazard of internal bursts or flakes, but the addition of special alloying agents (or in fact of *any* alloy) to this base composition may induce a tendency to flaking. Such alloyed steels must therefore be processed by proper slow cooling in bloom or billet form.

Addition of these special alloys has no effect, either beneficial or detrimental, on the cleanliness of the steel. Any standard alloy practice now in use which produces steel of a satisfactory degree of cleanliness will require no modification to produce an equally clean steel when using the special alloy agents. Exactly the same remarks apply to surface quality and macro-etch of treated as compared to untreated steels.

The picture as regards grain control is somewhat different, and some modifications of deoxidation practice may be required, depending upon the special alloying addition used. Some of them do not have any marked effect upon "inherent grain size"; that is, they do not seem to either coarsen or refine the grain. On the other hand, some do have a marked tendency to coarsen the steel; when these types of alloy are used, extra amounts of strong deoxidizers are ordinarily added to the ladle prior to the addition of the special alloy.

METALLURGICAL PRODUCTS ANALYZED SPEEDILY AND ACCURATELY

Slomin High Speed Electrolytic Analyzers

The rapid acceptance of this instrument for metallurgical analysis is outstanding endorsement of its proven ability and consistent reliability. Over 700 Slomin Analyzers are now in use in metallurgical laboratories.

Electrode design, current efficiency and improved procedures reduce deposition time formerly required by other systems as much as 25 to 40%. Under these high speed conditions hard, smooth, bright and closely grained deposits that firmly adhere to the electrodes are produced, thus assuring good reproducibility of results. Users report an accuracy of 0.01 to 0.04% for routine determinations.

Each model is portable and enclosed

in a welded steel case finished in acid resistant baked white enamel. The brushless motor is vapor tight and is therefore unaffected by corrosive fumes.

Both models have an electrically heated, rheostat controlled beaker platform for adjusting solution temperatures, and voltmeters and ammeters so that detailed studies can be made.

Each position of the two place analyzer is a complete circuit that operates independently of the other. Consequently this unit can be used for the simultaneous determination of two samples having widely divergent characteristics.

A laboratory manual of high speed electrolytic methods of analysis written by G. W. Slomin is supplied with each analyzer. Individual copies are available at \$1.50 each.

● 5-29460 Slomin Electrolytic Analyzer. One position. 5 Ampere Model, with Heating Plate. For operation from 115 volt, 60 cycle circuits. Each \$155.00

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● 5-29467 Ditto. But for operation from 230 volts, 60 cycle circuits. Each \$285.00

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● 5-29632 Corrugated Platinum Anode (Patent pending). Price subject to market.

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Literature on Request



E. H. SARGENT & CO., 155-165 E. Superior St., Chicago, Ill.
Michigan Division: 1959 E. Jefferson, Detroit, Mich.

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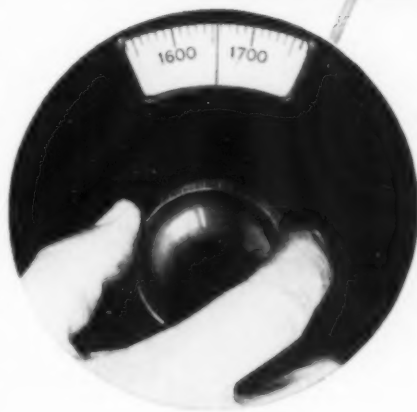
**AN INDICATING PYROMETER
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Here's a practical solution to wartime production problems of getting high-accuracy temperature information under today's speeded-up shop conditions!

Foxboro Potentiometer Indicators combine thermal precision approaching laboratory standards, with simplicity of operation that practically eliminates chances of inaccurate setting or reading by operators. Every detail is specially designed for ease and accuracy!

For example, the patented Foxboro Auto-Vernier Rheostat incorporates coarse and fine adjustment slide-wires in a single unit for standardizing the measuring circuit with precision. The extra-large dial provides an open, 17 inch temperature scale which can be easily read to very small units. Further, the vernier setting knob permits precision setting of the measuring slide wire.

These are merely two of the better-engineered features of Foxboro Potentiometer Indicators that give guaranteed accuracy of $1/4$ of 1% of scale value . . . and permit easy reading to $1/6$, or even $1/10$, of 1% of scale. Write for complete details in Bulletin A-305. The Foxboro Company, 52 Neponset Avenue, Foxboro, Mass., U. S. A. Branch offices in principal cities of United States.



Extra-large, extra-open dial of Foxboro Potentiometer Indicator enables quick, accurate setting. Built-in key-switches for 1 to 18 thermocouple connections also add to ease of reading.

Potentiometer Instruments by **FOXBORO**

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Intensifiers

(Continued from page 1069)

To illustrate a typical effect on a steel with naturally greater hardenability, some tests on NE1340 (0.40 carbon steel with 1.75% manganese) are reported. When oil quenched and tempered at 450° F. the yield points

averaged 226,000 psi. for the untreated and 252,000 psi. for the treated steel, and the tensile strengths 241,000 and 262,000 psi. respectively. These differences obviously are relatively unimportant, though it should be noted that the yield point of the treated steel averaged higher than the tensile strength of the untreated. The elongations, however, were 9.5% for the untreated and 13% for the treated, and the

reductions of area were 31% for the untreated, and 46% for the treated. These results give a merit rating, or "P-value" as it has been designated in the automobile industry, of 85 for the untreated, and 108 for the treated steel.

Notched-bar impact results as obtained by the Izod method may be illustrated by the following comparisons, all being average results from 0.40% carbon steels, quenched and drawn. With about 0.75% manganese (A.I.S.I. steel C-1040), drawn at 450° F., the impact values were 3 ft.-lb. for the untreated steel and 10 for the treated, while drawn at 900° F. they were 79 and 60 ft.-lb. respectively. This illustrates the previous statement that toughness is generally improved by treatment with the boron-bearing alloys when the steel is quenched and drawn at low temperatures, but not with higher tempering temperatures. Similarly with manganese up to 1.75% (NE1340) and specimens drawn at 450° F. the impact values were 9 ft.-lb. for the untreated and 17 for the treated steel; and when drawn at 900° F. they were 67 and 52 ft.-lb. respectively.

Considerable data on other low alloy steels support the same general conclusion regarding impact resistance.

As a summary of this discussion it may be stated that the chief "extra property obtainable in a treated steel" is an increase in hardenability, which varies in amount depending on the type of steel treated but generally is sufficient to give a Jominy value $1\frac{1}{2}$ to 5 times as great as in a similar untreated steel. "This improvement in hardenability produces an increase in strength in critical sections either with an increase in ductility and toughness, or without normal corresponding loss in ductility and toughness, depending on the magnitude of the strength increase," to quote the report mentioned in the beginning. ●

*Drawing with
all our might...*



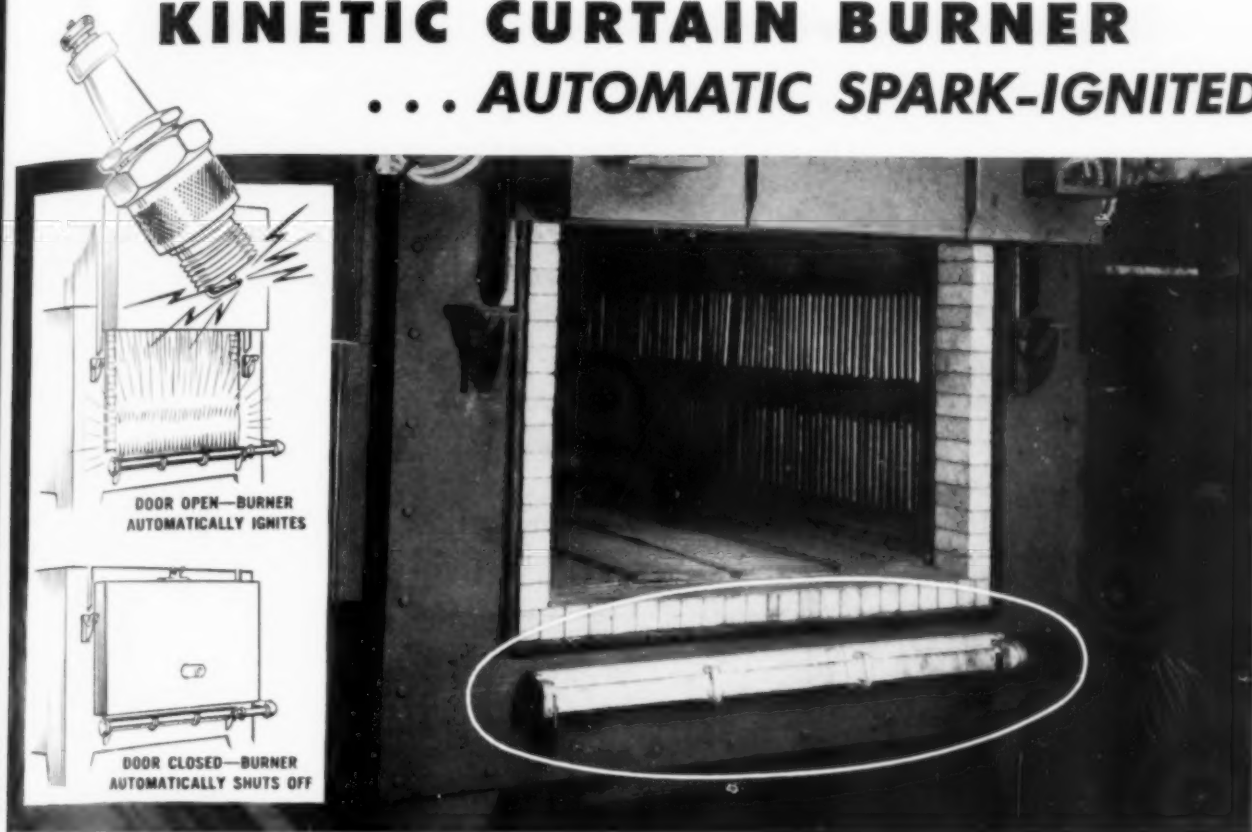
Continuously working at capacity, we are truly "drawing with all our might!" We are proud that Wilbur B. Driver Co. special alloys have so many vital war applications and of the part they are playing toward the final complete strangling of the "Unholy Three".

Perhaps we can help you make your product do its part more effectively or get on the job more quickly. Consult us for your requirements.

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NEWARK, NEW JERSEY



KINETIC CURTAIN BURNER ... AUTOMATIC SPARK-IGNITED



Positive protection of controlled furnace atmospheres is always assured by the National Kinetic Curtain Burner. The kinetic energy of the products of combustion interposes an impregnable curtain against the entry of foreign atmospheres. Whenever the furnace door is opened, the flame curtain is *instantly and auto-*

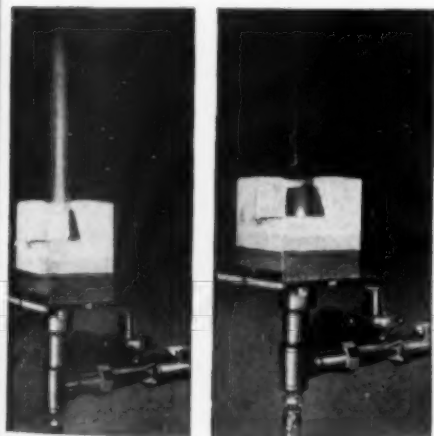
matically lighted by an electric spark. When the door is closed, the burner shuts off. At no time is the furnace atmosphere exposed to contamination.

Easily mounted under the doorsill, the burner is entirely outside the furnace. Prominent furnace manufacturers are now including it as standard equipment.

Latest developments in gas-burning equipment

Every specialty for the better, more economical use of gas is included in the National line, a few of which are shown on this page. Their construction assures the positive action which means *results* at minimum cost . . . many are the first of their kind in design and application.

Of special interest today is the use of National Blast Line Burners for mouth annealing of brass and steel shell cases. Their *continuous* flame permits accurate control of grain and ductility. These burners are also widely used for oven heating by direct fire.



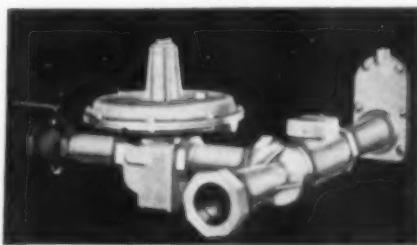
25:1 TURN-DOWN DOUBLE-FLAME HYPERBO BURNERS

The long turn-down range of these burners permits furnaces to be operated at temperatures in excess of 2000° or as low as 350° with one *psi* combustion air.



TORCH TIPS

These open-fired burners are noted for superior flame retention. Numerous small orifices assure a more uniform distribution of the piloting fringe gas and hence a more stable ignition of the main jet. Unique design protects metal in burner face from heat damage and greatly increases burner life.



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Automatically and exactly proportions gas and air for pre-mixing burner ports of all types. Accurate gas-air ratio control is as vital as good temperature control.

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SEND FOR
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*Shows many new technical
advances—features exclu-
sive, easy-selection charts.*

New Equipment and Products

Weld Testing

A spot weld testing machine, to check the strength of spot-welded samples, has been developed by the Baldwin-Southwark Div., Baldwin Locomotive Works, Philadelphia. For use in production-line testing of light metal fabrication, this machine is extremely rapid and simple to operate.

New Electrodes

Silver series welding electrodes have been developed by American Agile Corp., Cleveland, to answer the toolsteel and die salvaging problem. These electrodes are said to eliminate waste, inasmuch as a new and excellent cutting edge can be rebuilt on the worn tool shank. After the weld deposit is made, the tool is reground and goes back into use.

New Resistance Welder

New rocker arm resistance welder for the spot-welding of aluminum has been developed by Sciaky Bros., Chicago. Features include adjustable electrode tips, which may be set at any angle without impairing their proper welding position, for the welding of unusual shapes and sizes.

New Plant

Hydro-Arc Furnace Corp. is now located at the new plant at 561 Hillgrove Avenue, LaGrange, Ill. Company's arc furnaces for melting steel and iron are now lined up either for cold-melting steel and iron, or triplexing steel in Whiting Corp.'s new converter process.

Mounted Wheel Manual

With the important and rapid changes in production methods an urgent need has developed for published information on the proper application of mounted wheels. To meet this need Chicago Wheel & Mfg. Co., Chicago,



has published an informative booklet, profusely illustrated at exact size in color of all types of mounted wheels and a wide array of accessories for high speed portable equipment. Copies may be obtained by writing the company.

Transparent Cutting Oil

National Graphite Co., Inc. of New York City announces a new high quality coolant known as Konag Transparent Cutting Oil, made for severe cutting operations on tough steels.

It is said to increase cutting speed because of greater metal adsorbing oiliness at the cutting edge of the tool, and ability to

dissipate frictional heat rapidly. The clear transparent straw color enables the operator to watch his work.

Metal Cleaning

Designed to degrease the interior of shell casings as well as exteriors, Phillips automatic shell degreaser utilizes a conveyor belt equipped with swiveled basket carriers which automatically and continuously place shells in position so solvent can be forced into them under pressure. Manufactured by Phillips Mfg. Co., Chicago, these degreasers for handling 20 to 75-mm. shells are portable, requiring neither steam, water nor gas connections.

Arc Welder

New line of Herco arc welders is announced by Hercules Electric & Mfg. Co., Inc., Brooklyn. Precision heat control enables the operator to get minute heat adjustments over the entire transformer range. The relative absence of "arc blow" permits use of large diameter electrodes, which means more metal deposited in less time and speeds production.

Aircraft Riveting

Designed to afford increased speed and efficiency of flush riveting in aircraft production, a new Rivitor manufactured by Tomkins-Johnson Co., Jackson, Mich., is air powered and has an automatic feed and setting mechanism. Simplified construction uses less-critical materials and requires fewer parts.

Today's Destination:

BATTLE FRONTS

Tomorrow's:

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TENUAL ALUMINUM CASTINGS are proving their worth on far-flung battle fronts in planes . . . tanks . . . ships. And our castings will "come through" under all conditions because of our ability to meet the most rigid specifications of the armed service with speed and quantity production. This will be your guarantee of receiving quality sand and permanent mold aluminum castings when our shipping tags can again read: Destination U. S. A.

Illustration shows careful water pressure testing of an important aircraft aluminum casting

TENUAL

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MAKERS OF QUALITY SAND AND PERMANENT MOLD ALUMINUM CASTINGS



New Equipment

Superfinishing Machines

Improvements have been made on the Foster 4 by 8-in. general purpose superfinishing machine, and a new and longer 4 by 36-in. model has been added to the line offered by International Machine Tool Corp., Elkart, Ind.

These general purpose superfinishing machines are capable of developing an extremely accurate and fine finish of 2 to 5 micro-inches on cylindrical work such as shafts used in aircraft engines, where surface scratches and defects must be eliminated.



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FURNACES
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ARMAMENT
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ELECTRIC AND FUEL FIRED
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AGAIN ROCKWELL ENGINEERS BOOST WAR PRODUCTION!

A new Rockwell Gas Fired Unit hardens, quenches and tempers high explosive shells in one continuous operation. A single operator places shells on the conveyor at the charge end of the hardening furnace—thereafter all operations are continuous. Both the hardening and draw furnaces are provided with automatic proportioning burners and control instruments so that any draw specified by the Ordnance Department may be easily obtained.

Shells are carried through both furnaces by an oil hydraulic pushing system with time cycle control. The method of quenching gives a very uniform hardness and minimizes any danger of soft spots due to vapor pockets or other causes.

If MORE PRODUCTION is your problem, write or wire us. Rockwell's wide experience in heat treating will help you.

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Shafting Manual

Section I of the Supplement Manual which follows the 50th anniversary book issued by Bliss & Laughlin, Inc., Harvey, Ill., has just been published. It includes 52 pages of technical data on cold finished bar steels and shafting.

Testing Chamber

Because many precision instruments must function equally well in Iceland or sun-baked Libya, this new chamber has been developed for testing instruments under extremes of cold and heat. Manufactured by American Coils, Inc., Newark, N. J., its range of operating temperatures extends from -55°C. to $+70^{\circ}\text{C.}$ It includes apparatus for mechanical refrigerating and electrical heating.

Salt Bath Furnace

Electric pot-type salt bath furnace for cyanide hardening of toolsteels has been developed by H. O. Swoboda, Inc., New Brighton, Pa. Designed for production work, its operating temperature is normally 1650°F. ; however, precise controls permit the bath to be used at considerably lower temperatures for tempering.

Deep Drawing Press

One of the world's largest self-contained deep metal drawing presses has been completed by Hydraulic Press Mfg. Co., Mount Gilead, Ohio. Press embodies two hydraulic actions, a 3500-ton downward acting die platen and a 1000-ton hydraulic die cushion in the press bed. This massive press is capable of deep drawing heavy steel plate to a depth of 18 in.

Drying Oven

New infra-red drying oven for the polishing and buffing trade is announced by Park Chemical Co., Detroit. A portable unit, the oven will accommodate a large number of polishing wheels and takes up very little space. Drying time on polishing wheels can be cut from 24 hr. to 30 min. with this unit.



Let a Meehanite Foundry
Solve Your Casting Problems

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Farrel-Birmingham Co., Inc.

Bridgewater, Mass.
The Henry Perkins Co.

Buffalo, N. Y.
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Chattanooga, Tenn.
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Chicago, Ill.
Greenlee Foundry Company

Cincinnati, Ohio
Cincinnati Grinders Incorporated

Cincinnati, Ohio
The Cincinnati Milling Machine Co.

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Fulton Foundry & Machine Co.

Denver, Colo.
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There are twenty-one types of Meehanite, each having a different combination of physical properties aimed toward meeting definite service requirements.

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Varying with the requirements of the service, Meehanite in its several types (as cast) produces tensile strengths up to 55,000 lb. p.s.i.; compressive strengths up to 200,000 lb. p.s.i.; moduli of rupture in bending from 61,000 to 93,000 lb. p.s.i. These and other properties such as yield point, modulus of elasticity, hardness, torsional and shear strength, fatigue strength, etc., are known and reliable.

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Machinability rating tests prove Meehanite more machinable than steel or alloy iron castings. This important advantage of Meehanite is due to two factors, (a) the constitution of the metal frequently permits substantially increased machining speeds, (b) dimensional accuracy and smooth cast

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A unique combination of high damping capacity and high strength gives Meehanite castings a prominent position in the construction of precision machinery, and in highly stressed machinery parts where weight, noise and possibility of fatigue failure must be kept to the minimum.

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MEEHANITE RESEARCH INSTITUTE, 311 Ross St., Pittsburgh, Pa.



Lead Being Stockpiled

(Continued from page 1039)

but in 1940, 128,680 tons. Mexico's total shipments to us, including ore, base bullion, and refined lead, were 20,000 tons greater than this, however. In fact, total imports of lead of all kinds into

self-sufficient U.S.A. jumped from a dribble of 23,615 tons in 1936 to 282,492 tons in 1940. Imports of bullion and ores in 1942 will be much higher.

Production of new lead in our own country in 1941 jumped

to about 110% of 1940, and primary production this year is expected to be higher again. Secondary metal recovered from scrap normally serves over 25% of our needed supply, but, as remarked above, this source is declining in importance, both relatively and quantitatively.

To guard against any contingency, the Metals Reserve Co. has been accumulating a stockpile of lead. While this has not yet reached the desired size, present conditions indicate that it will do so.

A quota system, which provided that a certain amount of his production must be set aside each month in a "bank" or a reserve by each lead producer, was instituted by WPB, so that emergency requirements could be met from this stock. Easing of the lead situation has made this "bank" unnecessary, so the lead pool was suspended in October. Meanwhile, due to sustained domestic production and increased imports, plus decline in demand, the stockpile has improved substantially.

There is relatively far more lead in relation to demand than there is copper, tin, or zinc. Because of the desperate shortage of these metals, WPB now recommends that lead be substituted for them wherever possible. This, however, does not mean that we should try to use as much lead as possible. Substitution is the thing, not just consumption.

Within the bounds of lead use allowed by Governmental orders, and in relation to carefully calculated military, naval and essential needs, it appears that the supply of lead not only will balance with requirements this year, but will give us a good reserve supply owned by the Government. Lead is less short than any other of the so-called critical materials, though the need to be prepared for possible future requirements must still be emphasized.

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CASE CHARACTERISTICS

- 1 The case produced is similar in composition to the usual gas and pack carburized cases, but in addition contains a small amount of nitrogen in surface layer.
- 2 Eutectoid plus hypereutectoid zones comprise roughly 40% of the total case. Approximately 75% of the total case is 0.40% carbon or higher.
- 3 A hardness of Rockwell C-67 can be developed on SAE 1020 steel.

OPERATING CHARACTERISTICS

- 1 This cyanide deep-case bath is designed for operating temperatures of 1700°F to 1750°F.
- 2 The rate of cyanide loss at temperatures of 1700°F to 1750°F is approximately 1/8 of 1.0% per hour.
- 3 The molten density of the bath at 1700°F is 136 pounds per cubic foot.

When considering installation of new case hardening equipment, as much as 50% can be saved on the initial investment by setting up for salt bath treatment.

If your requirements call for case depths of 0.001" to 0.150" Cyanamid Deep Case, Aerocarb*, Aerocarb, sodium cyanide, or one of our sodium cyanide case hardening compounds, 30%, 45%, 75%, can be relied upon to provide satisfactory results at low cost.

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Sponge Iron

(Continued from page 1047)

If the establishment of the sponge iron process requires diversion of materials of construction from essential uses such as ships, blast furnaces, aluminum plants, etc., then the value of the availability of sponge

iron would be counteracted by loss of production in other places. Hence, it is necessary to weigh the need for sponge iron producing capacity against its cost in other strategic products. (Actually it becomes a question as to whether a scrap shortage should be averted by construction of sponge iron capacity or of more blast furnaces.)

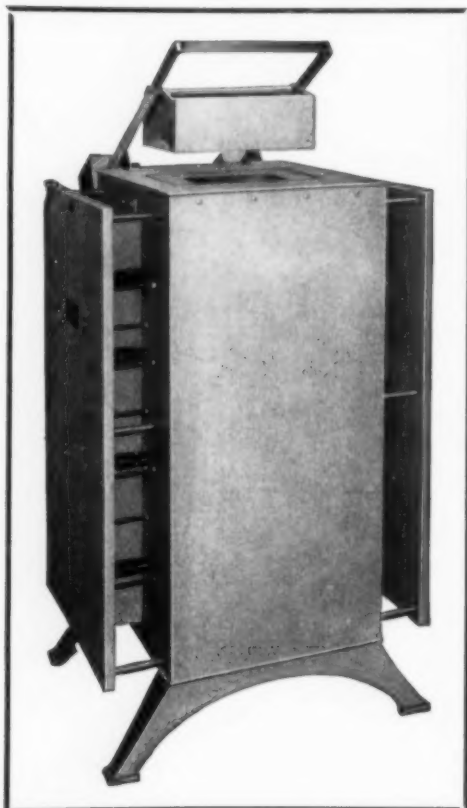
12. The sponge iron process is not established on a commer-

cial size scale, and experimental demonstrations have not proved that large operations can be established with certainty in any given time. The production of sponge iron is still experimental and furthermore much test work (costly in terms of steel production) would be needed before sponge iron could be used regularly for steel production.

13. The blast furnace production of pig iron is a long established operation, efficient in use of labor, raw materials and by-products. Its product, pig iron, is the most satisfactory form of iron from which to make steel. Hence, additional iron to supply the nation's steel requirements can best be made by the production of pig iron in the conventional blast furnace.

14. There are so many unfavorable aspects to the sponge iron process that its development would appear to be a retardation of the over-all war effort. Diversion of our pure iron ores, diversion of electric furnace capacity or of materials of construction, diversion of raw materials, labor and energies would be a high price to pay for the development of a substantial production of sponge iron whose utility is so questionable. The establishment of sponge iron plants would therefore be wasteful in over-all productive effort.

15. The undertaking of a large research and development program for the production of sponge iron as a substitute for scrap is inadvisable at this time. Research and development are justified, however, for the development of a suitable process for making powdered iron for use in the new "powder metallurgy". Since the requirements for powdered iron are measured in thousands of pounds and the current price 10 to 12¢ per lb., processes similar to the sponge iron process should apply. Such a program of investigation is now under development for the War Production Board.



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Caustic Embrittlement

■ TWO IMPORTANT publications have recently appeared on the "Intercrystalline Cracking of Boiler Steel and Its Prevention", the first a general summary of what is known about the problem (Bulletin 443 of the U. S. Bureau of Mines) written by two of the leading investigators, W. C. Schroeder and A. A. Berk, and the second a "Symposium on Caustic Embrittlement" by the Joint Research Committee on Boiler Feedwater Studies (*Transactions of the A.S.M.E.*, July 1942). Extracts from each are appended.

Intergranular failure along riveted seams in steam boilers has now been a matter of concern for more than 30 years. Attempts during the first half of this period to correlate the incidence of cracking with various

factors led, in Europe, to major emphasis upon methods of fabrication; in the United States, concurrently with efforts to improve boiler manufacture, attention was directed particularly toward control of boiler-water composition. The latter found official expression in the A.S.M.E. Boiler Code of 1926, which established ratios of sodium sulphate to alkalinity of the boiler water, such ratios then being considered proper to eliminate cracks in riveted boilers at various operating pressures.

It was early discovered that the cracks occurred in riveted joints, sometimes radiating out from rivet holes. Likewise the cracks extend through the steel along the crystal boundaries, with little or no sign of accompanying corrosion. It is accepted

by all authorities that intergranular cracking of a riveted seam in a boiler is evidence of the simultaneous operation of certain essential mechanical and chemical factors: Boiler water must have concentrated greatly, a hundred or a thousandfold; the concentrated solution must have been in contact with steel under high applied or residual stress; and the composition of the solution must have been such as to lead to localized corrosion at grain boundaries, rather than general attack.

Much metallurgical work has been done in an effort to manufacture boiler steel that will be free from this type of failure. Particularly recommended was the so-called Izett steel, made in Germany—a killed steel with small fractional percentages of nickel and chromium but relatively high in aluminum and nitrogen. This proved no better under test by the Bureau of

(Continued on page 1136)

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Embrittlement

(Cont. from p. 1134) Mines than aluminum-killed steel made in America. The investigators say:

"To the writers' knowledge, no steel suitable for boiler construction has yet been developed that is immune to embrittlement. As many low alloy steels are now

available, this should offer a fertile field for investigation. A steel of the proper characteristics would be exceedingly valuable in locomotive boilers."

A long step in advance was the invention of an embrittlement detector by Schroeder. It consists of a rectangular block with threaded axial hole so that the block can be made a part of a pipeline carrying the hot boiler water. Through one face of the

block is bored a small passage to the central hole, but leakage is prevented by a test piece securely bolted down to the face of the block. One end of this test piece is bent slightly back, and can be stressed at its bend by a set screw; in fact, it can be prized far enough back so that a tiny bit of the hot boiler water escapes. This diffusion is best detected by holding a cold glass or mirror over the end of the unit, and the most desirable adjustment will show only a slight haze of condensed steam. The opening therefore is so small that the boiler water can diffuse through it only very slowly. As this occurs, the heat will cause evaporation toward atmospheric pressure to produce a more concentrated solution. Still further from the opening more evaporation will occur, and the boiler water is quite concentrated. Next, sodium salts begin to crystallize from solution, and finally substantially all the water is evaporated.

The rate of leakage must be confined within certain limits. If none occurs, concentration is not possible. On the other hand, if the opening is too large, the water will rush out so rapidly that concentration may not occur in contact with stressed metal.

Use of this detector during the past four or five years has revealed disconcerting deficiencies in the action of some chemicals that have previously been relied upon to stop embrittlement. Its use has also emphasized that new boilers may be protected by two entirely different methods: (a) To build boilers in such a manner that they are not susceptible to cracking, or (b) to treat the water so that it will not cause cracking.

Use of welded drums provides satisfactory means for eliminating the major source of trouble in stationary boilers, but general adoption of this practice for locomotive boilers is not yet deemed feasible. (Cont. on p. 1138)



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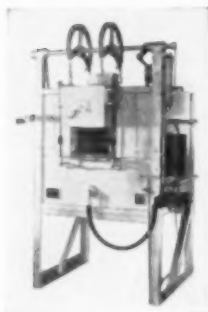
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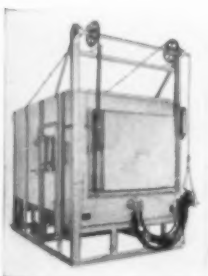
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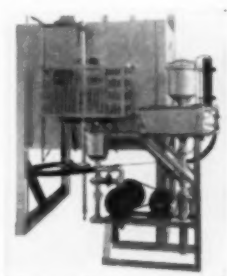
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Embrittlement

(Starts on page 1134)

Final proof of the value of the embrittlement-detector method of testing has been provided by the Chesapeake & Ohio Ry. This work was not a result of academic interest in the embrittlement problem, but

instead was due to the pressing necessity for preventing cracks in 22 to 40 locomotive boilers each year. It furnished a chance for determining the effect of protective chemicals in a number of operating boilers otherwise probably destined to crack. At the same time, it directly correlated the action of the water on specimens in the embrittlement detector and in the cracking of locomotive boilers.

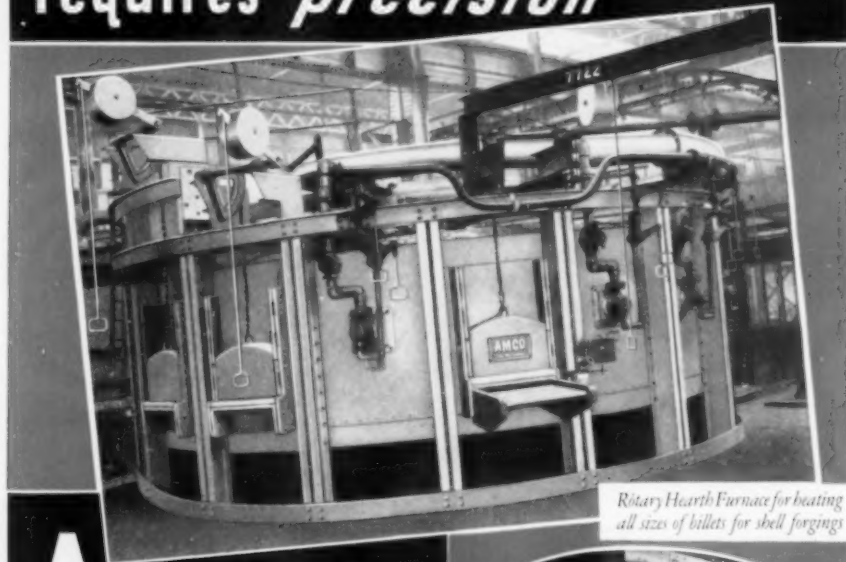
During each six months from 1934 to 1938, there were never less than nine cracked boilers and a peak of 21 was reached. During 1938 and 1939, treatment was started with waste sulphite liquor—an inhibitor largely by virtue of the lignin it contains. No appreciable decrease in cracking was noted during 1939, nor was it expected, since old cracks in the boilers must be found and repaired, a process that would probably require a few years for completion. In 1940, the last six months showed a decrease in the number of cracked boilers. In 1941, cracking rose in the first six months but results for the last six months are extremely gratifying, for only two boilers were found cracked. This is particularly significant since the engine mileage during this period has been much greater than that for any similar period in the previous years which are shown. The results furnish strong evidence that this railroad is on its way to the elimination of its embrittlement troubles.

The fact that the decrease in engine cracking follows the elimination of cracking in the detector specimens indicates that the establishment of non-embrittling conditions, according to this test, is a strong criterion that the water can be used in the boiler without danger. On the other hand, if the boiler water cracks the detector specimens, it will not necessarily crack the boiler, yet it is difficult to guarantee that conditions do not exist in service or will not arise in the boiler structure from which cracking may result.

A practical program to obviate cracking in riveted seams is suggested by Partridge and associates in the A.S.M.E. Symposium. Test data show that sodium sulphate will not prevent cracking, nor do sodium sulphate and sodium chloride at pressures above 250 psi. Likewise, a boiler water containing appreciable

(Continued on page 1140)

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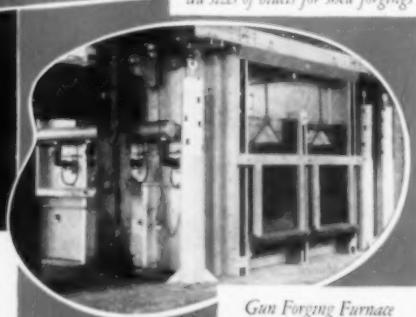


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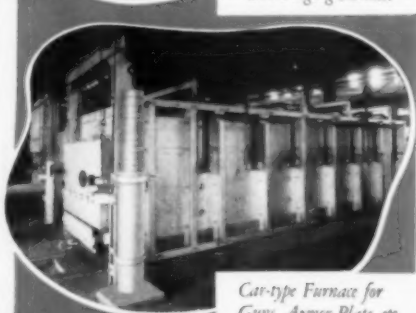
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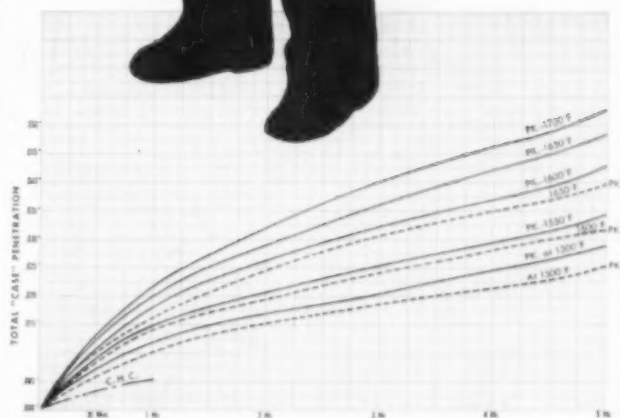
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Embrittlement

(Starts on page 1134)

NaOH cannot be treated with sodium phosphate to prevent cracking. On the other hand, quebracho tannins, lignins and NaNO_3 appear to inhibit embrittlement when properly used.

It would therefore seem logi-

cal neither to accept with blind faith the semi-official sulphate-alkalinity ratios, nor with blind zeal to replace them with some other system of ratios based upon the effect of tannin or any other proposed inhibitor. Instead of the formulation of rules, full advantage should be taken of the testing methods now available, and each operator should determine, with whatever assistance he may choose, the conditions

which he can most economically and effectively maintain in his own boilers to minimize the likelihood of cracking.

If he has no boilers with riveted seams, the operator may feel justified in ignoring the problem. He may still, however, wish to take precautions to avoid the admittedly rare possibility of intergranular cracking in tube ends. Along with the operator more directly concerned because of riveted construction, he can, by means of the embrittlement detector, first test his boiler water under existing operating conditions. If specimens crack in repeated tests, he can then explore, in a consistent manner, the effect of any changes in treatment. Experience to date indicates that he will be likely to find practical conditions under which the steel of the detector specimen will remain uncracked.

Having once achieved favorable conditions, there is then much to be said for using the detector as a continuous indicator to be sure that some apparently unimportant change may not make the boiler water again capable of cracking steel. Altogether, the use of the embrittlement detector in this manner may prove as desirable as the measurement of carbon dioxide in the flue gas.

Perhaps the answer in any particular case will lie in the use of tannin; on the other hand, nitrate may demonstrate its superiority, or the reduction of the sodium hydroxide content of the boiler water substantially to zero by maintaining alkalinity with phosphate may prove satisfactory and desirable. The emphasis does not rightly belong upon any particular chemical means of inhibiting cracking; instead, the important fact to be realized is that the re-investigation of boiler metal cracking in recent years now has produced a means of measuring the elusive chemical factor in this type of failure.



In all sincerity we wish you

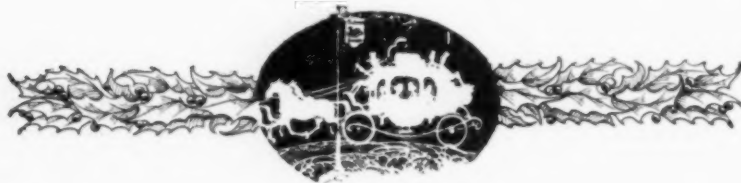
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A Bright, Prosperous New Year

and an early peace that will be lasting and just

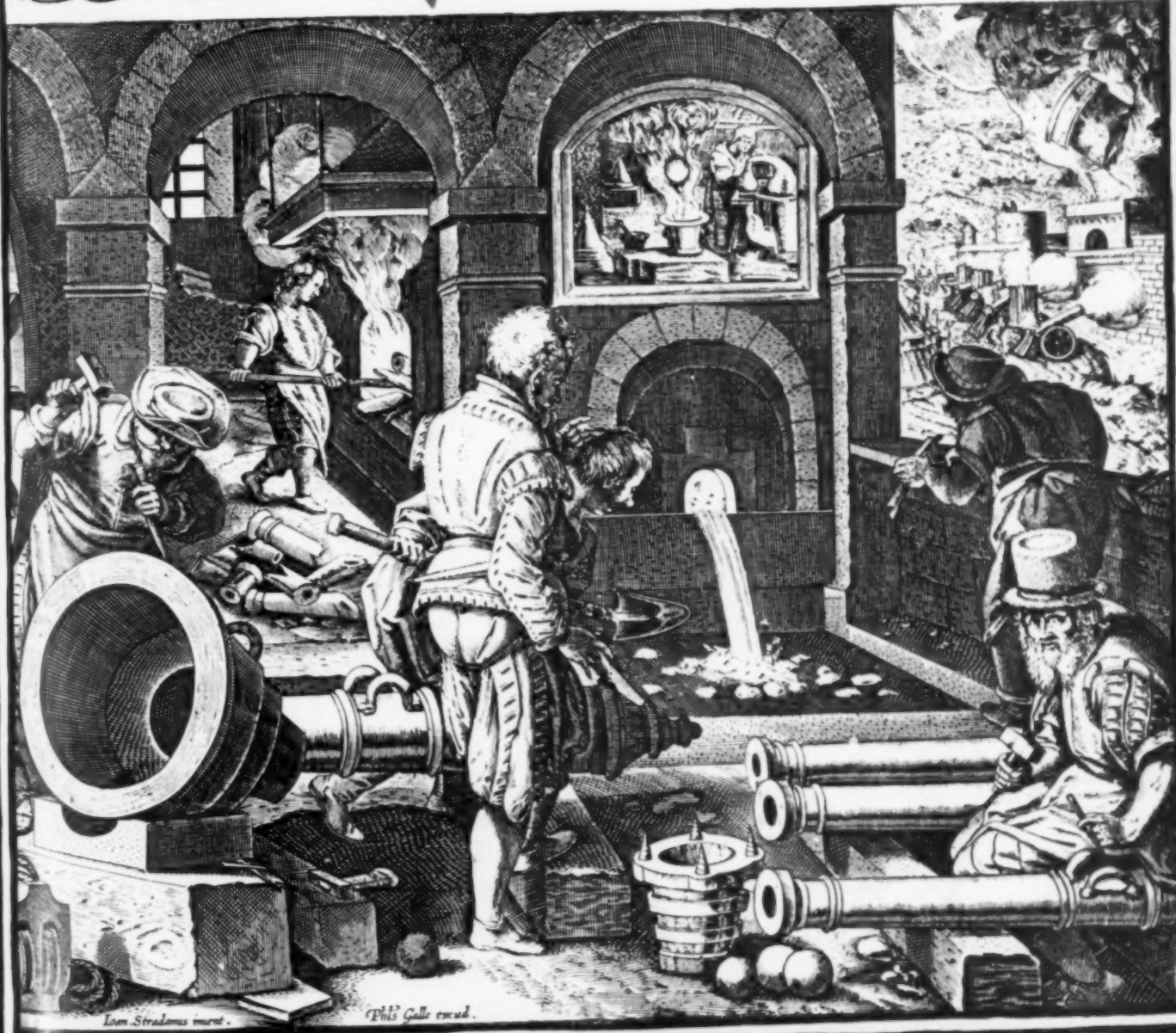
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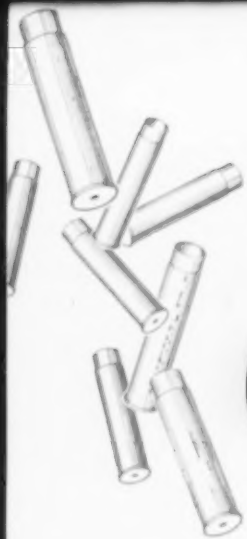
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economical and flexible than a single continuous convection furnace of equivalent capacity.

These three batch furnaces are used for the four process anneals. A fourth batch type furnace (not shown) is used for the final stress relief anneal.

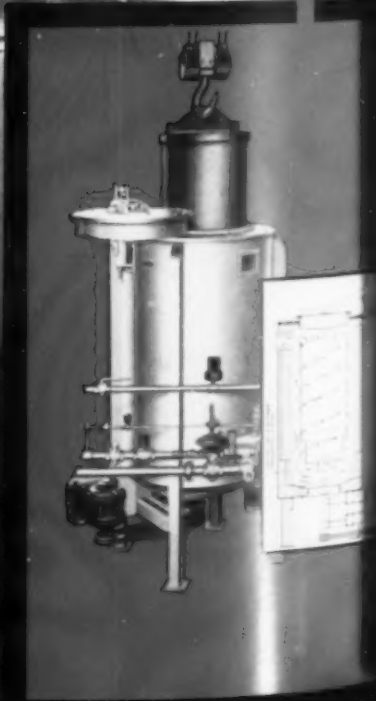
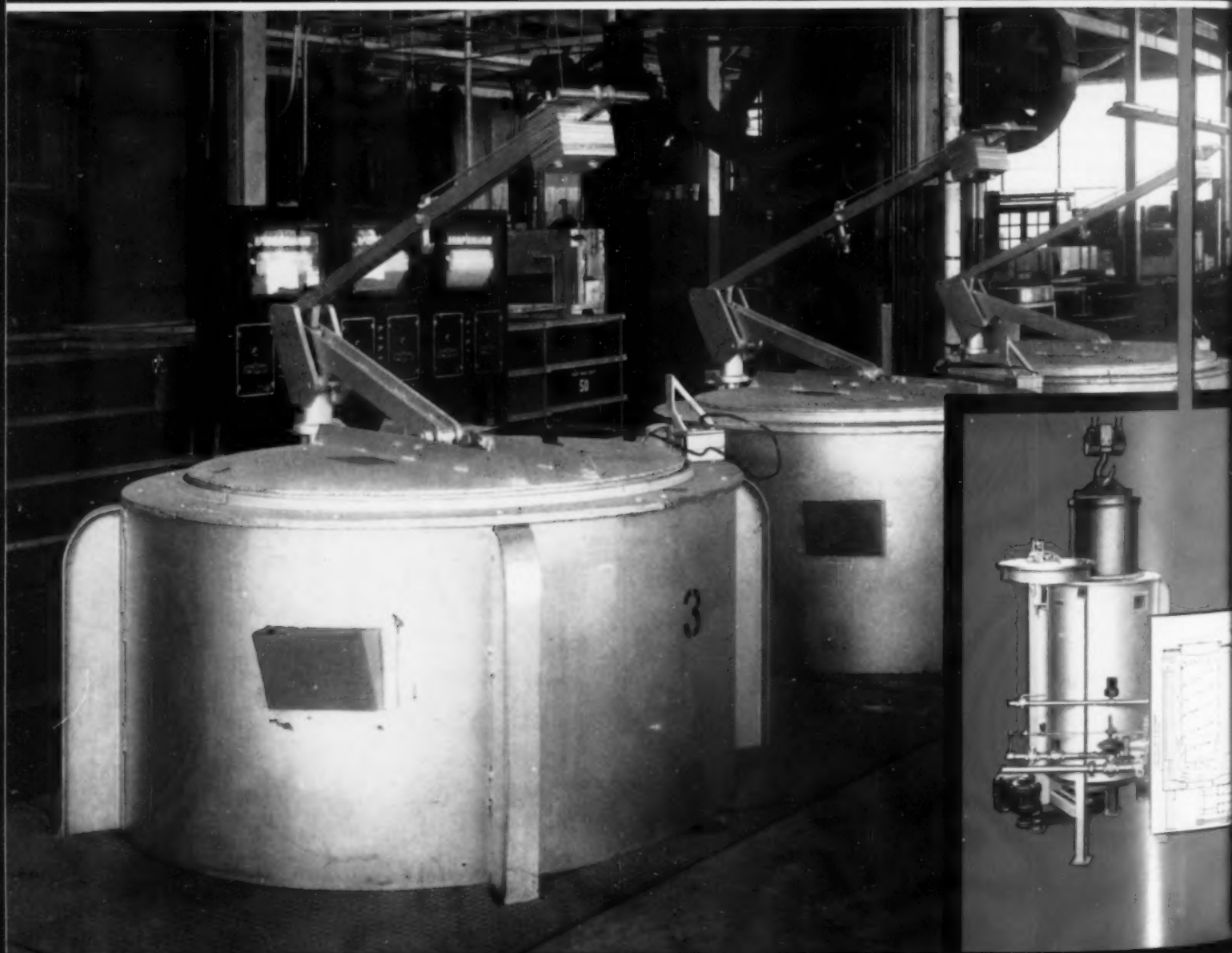
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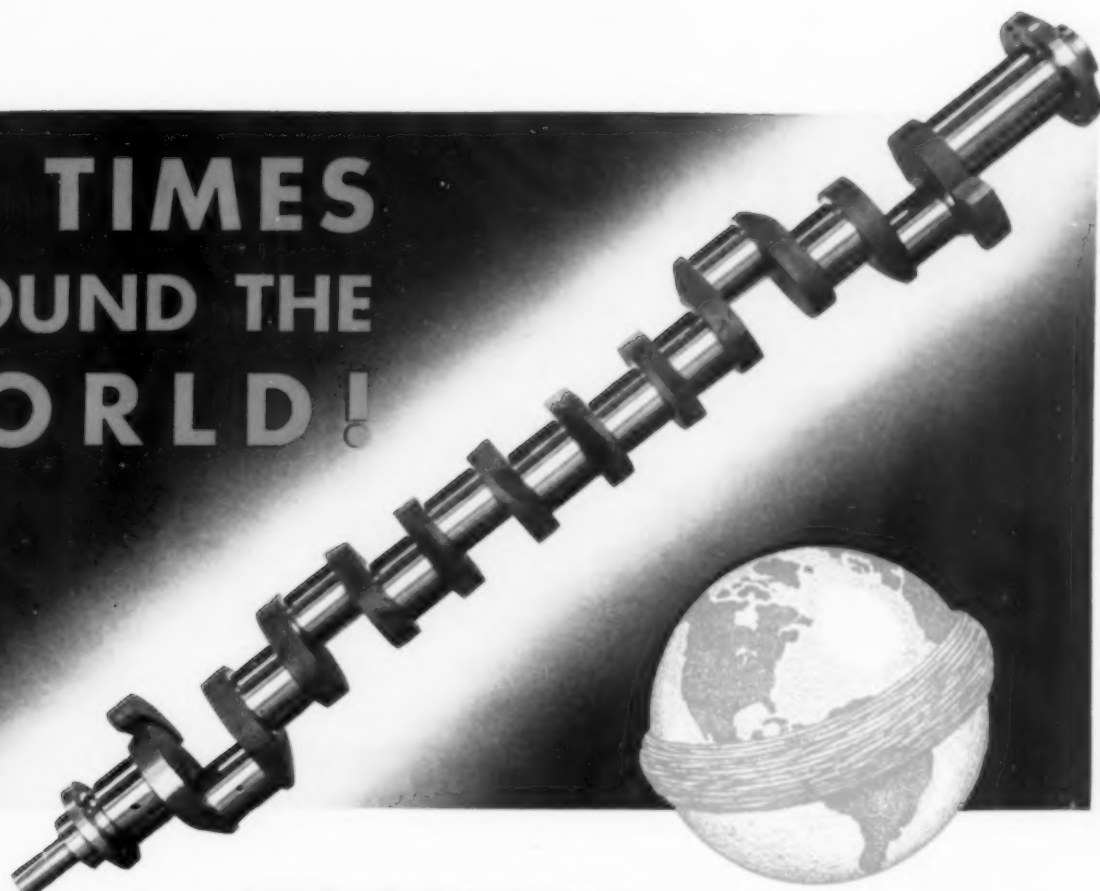
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ONLY 1/1000-inch wear on the crankpins after piling up a service of 1,000,000 miles . . . a distance equal to 40 times around the world! That's the record of one veteran TOCCO-hardened crankshaft on one of the country's fastest streamliner trains. Hundreds of thousands of other TOCCO-hardened crankshafts are giving similar performance . . . giving 5 to 10 times normal life . . . avoiding delays for engine overhauls . . . keeping engines of the United Nations on the straight path to Victory.

TOCCO-hardened crankshafts are used by the firms listed.

Investigate TOCCO for improved and faster hardening, annealing, brazing and heating.

THE OHIO CRANKSHAFT COMPANY
Cleveland, Ohio



TOCCO

World's Fastest, Most Accurate Heat-Treating Process

THESE ENGINE BUILDERS USE TOCCO-HARDENED CRANKSHAFTS

Caterpillar Tractor Company
General Motors Corporation
Seven divisions making trucks and diesel engines.
Hercules Motor Corp.
International Harvester Co.
White Motor Company
Worthington Pump & Machinery Corp.
and many others.

**HARDENING
ANNEALING
BRAZING
HEATING** for
forming and forging

100,000 More Tons of Steel for Victory with Compliments of Basic Engineers

IN the year since Pearl Harbor, Basic service engineers have installed Ramix bottoms in 39 open hearth furnaces and major repairs in many more. Each job has meant a saving of 5 to 10 days in construction time.

By getting these furnaces into production so much sooner, operators have been able to turn out nearly 100,000 tons more steel than would have been possible had conventional burned-in magnesite-and-slag bottoms been installed.

Every open hearth and electric furnace man today knows Ramix. Of 188 basic steel plants in the

United States and Canada, 147 or 78.2% are using this cold-ramming, quick-setting magnesia refractory. Of 95 electric steel producers, 75 or 78.9% have one or more hearths of Ramix. Many others are using it as a repair material. Operators and engineers alike subscribe to the belief that a Ramix hearth is as near foolproof as present knowledge can build.

Basic Refractories, Incorporated offers this product and the services of its field engineers to assist any and every steel plant in producing the maximum tonnage of steel which is needed to bring Victory to American arms.



BASIC REFRACTORIES, INCORPORATED

845 HANNA BUILDING ● CLEVELAND, OHIO

*Represented in Canada and Great Britain by
Canadian Refractories, Limited, Montreal, Quebec*



Micromax, hung in improvised mounting, works while it waits for its steel panel to arrive. With it to help him, the furnace operator gets much closer control of a frit smelting furnace in plant of U. S. Stamping Co.

ENAMEL WARE MFR. STEPS UP PRODUCTION By Using Micromax Control for Frit Furnaces

Faced with the need for a big increase in the frit-smelting capacity of its gas-fired pot furnaces, the U. S. Stamping Co. has found Micromax Pyrometers "very helpful" in securing the close, dependable temperature-control which is necessary to such an increase.

The instruments for one furnace consist of a Micromax Round Chart Recorder, range 1100-2300 F, and a 24-inch open-end Rayotube radiation-detector. The Rayotube is mounted in an iron tripod on the furnace roof. Its open-end tube extends through a hole in the roof (to which it is of course luted with fire-clay) and is aimed at the surface of the charge in one of the pots. The Micromax Pyrometer to which the Rayotube is connected records this radiation as temperature, so that when the workmen regulate the fuel valves, they are being guided by the radiation from the surface of the bath, instead of depending, as they formerly did, on the temperature of the furnace. The result is a uniformity of temperature never achieved before in these furnaces.

If the benefits of automatic temperature control of the furnace are desired in such an application, the best practice is to use a closed-end Rayotube, (instead of the open-end one) in the furnace roof, and to equip the valve and the Micromax Pyrometer for full-floating, proportional Micromax Electric Control. Under this system, the Micromax brings the furnace up to temperature on the basis of the closed-end Rayotube, and thus lets the furnace itself select the fastest heating rate which it can stand, and then, when at temperature, call for such heat as it needs to maintain its temperature.

The correct control system, for any war-busy furnace, will be gladly selected for you if you will forward details of your problem.

Jrl Ad ENT-0600C(53)



LEEDS & NORTHRUP COMPANY, 4927 STENTON AVE., PHILA., PA.

LEEDS & NORTHRUP

MEASURING INSTRUMENTS • TELEMETERS • AUTOMATIC CONTROLS • HEAT-TREATING FURNACES



Carburizing The New Alloys Is Helped By Four-Factor Control

The fine results being secured with the new low-alloy steels are, of course, largely due to successful heat-treatment — and, in more than a hundred plants, this heat-treatment consists largely of Homocarb Method Carburizing. For this method gives the close, constant, accurate control of carburizing, which is increasingly needed as the percentages of alloying metals are reduced. Homocarb regulates four important factors:



Typical Homo-Carburized parts for machine tools

1. Quality of Carbon Source. The gas which supplies the work with carbon comes from a special fluid which is of assured, uniform, lab-controlled purity. This gas is pushed into every part of the furnace load by means of a Homo Method fan; so that carburizing action is uniform throughout.

2. Supply of Carbon Source. A precise injector-pump automatically feeds the desired amount of Homocarb Fluid into the furnace, so that amount of carbon supplied is exactly what the metallurgist desires.

3. Time of Carburizing. The equipment's Micromax Controller records the length of time, so that this factor can be exactly regulated.

4. Temperature. A Micromax Recording Controller holds the temperature at the desired point, and records the heating rate, the temperature and duration of soak, and the time of removal from furnace. Records are permanent; analyzed in the light of results, they end uncertainty.

With these 4 factors under control, the heat-treat has a precision tool for carburizing; it saves time, space, work and rejects. For further information, see our Catalog T-623, or put your problem directly up to us.



What the clock manufacturers are making would alarm Hitler

Alarms and other clocks may not be as plentiful as they once were . . . although it is believed there will be enough for every war worker. But fewer clocks, and fewer everything for civilians, is good news for Americans because it is the worst of news for Hitler.

In converting production facilities from clocks to war essentials, manufacturers were able to overcome new problems easily and quickly in cooperation with the Revere Technical Advisory staff. For in all problems of

copper and its alloys, Revere supplies a service, in addition to sound metals, that helps untie the knots of processing and fabrication.

Every ounce of copper our country can produce goes directly into war essentials. Fortunately, Revere is well equipped, with modern plants, improved machines and advanced techniques, to assume a heavy responsibility in meeting critical needs. And Revere research is continually uncovering new knowledge about copper to help make our arms more swift and sure.



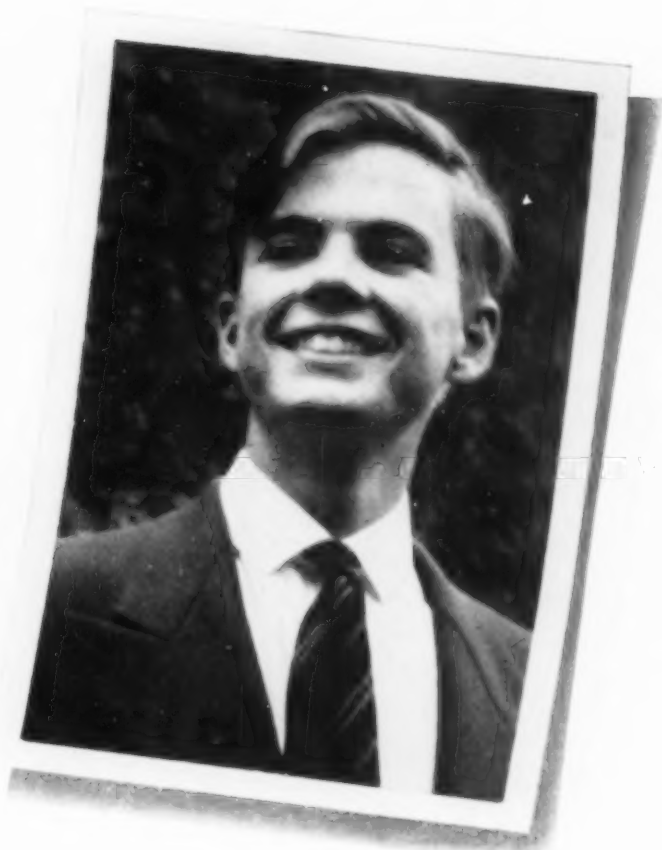
The Revere Technical Advisory Service functions in (1) developing new and better Revere materials to meet active or anticipated demands; (2) supplying specific and detailed knowledge of the properties of engineering and construction materials; (3) continuously observing developments of science and engineering for their utilization in production methods and equipment; (4) helping industrial executives make use of data thus developed. This service is available to you, free.

REVERE COPPER AND BRASS INCORPORATED

Founded by Paul Revere in 1801

EXECUTIVE OFFICES: 230 PARK AVENUE, NEW YORK

Son...



HE has just turned eighteen. Shaves twice a week and maybe a hair or two is sprouting on his chest. He shies away now when his dad tries to be affectionate and we noticed some lipstick on one of his handkerchiefs after a country club junior dance not so long ago. But it seems only yesterday, perhaps it was the day before, that he was a chubby legged kid swinging from the arch of the doorway, leading to the dining room, in a gadget that was something like a breeches buoy and he was sucking at the end of a turkey bone.

He went back to school this Fall, a tall, athletic lad, budding into manhood, but there was something else on his mind beside the football and hockey teams or the little blonde girl with whom he had "palled" around during the Summer. It seems as though he was listening for a certain call—the Clarion call that poets sing about—and, perhaps we just imagined it, but we thought we saw an upward jutting of his chin, a certain light in his eyes, and a sort of a rearing-to-go expression in his face.

It chilled us a bit in the region of our heart, when we thought of his discarding the sports coat for the "O.D." of the Army or the blue of the Navy. There

was a bit of a catch in our throat as we thought of his putting aside his football helmet for one of steel; of his hanging up his hockey stick and reaching for a gun. After all we still regard him as just a little boy.

They tell us that the eighteen and nineteen year old lads are to be called to the service. When that day comes to us there will be prayers, but no tears. We shall not mourn nor shall we be fearful. Rather there will come welling up from our hearts that warm feeling of pride that millions of other parents will sense when their beloved lads marched away. Our lad is no different than the others. We are no different than other loving parents, nor is our sacrifice any greater. They are going to make great soldiers, sailors, marines and fliers out of these youngsters. And they will become a mighty force when they take their places beside their brothers in arms. They too know what they fight for. They too know full well of the sacrifices that must be made before the evil powers that threaten the world can be overcome.

And let us not forget that they are counting on us. They know that we shall not fail them.

God be with them and their brothers.

THE CARBORUNDUM COMPANY, NIAGARA FALLS, N. Y.

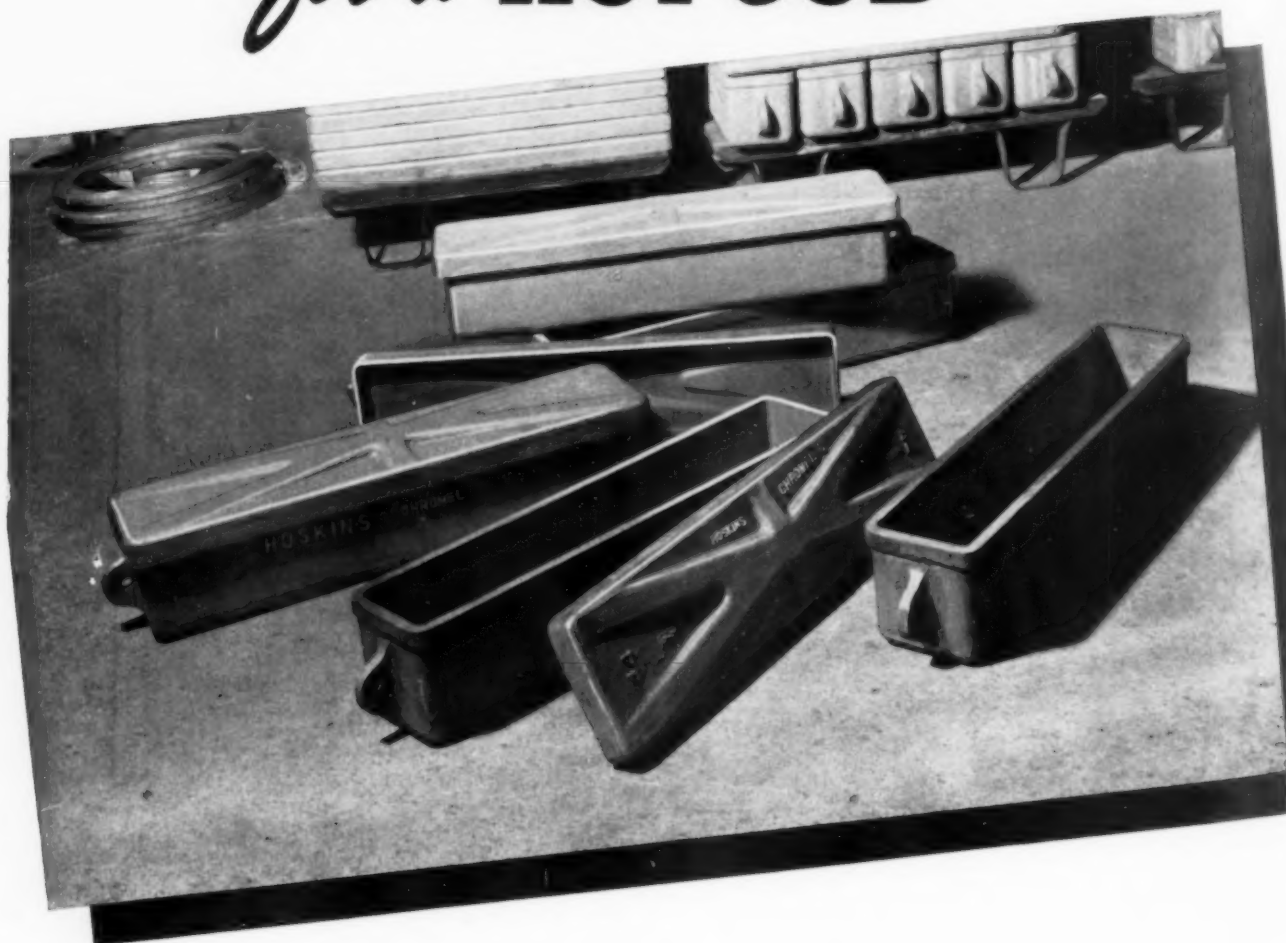
REG. U. S. PAT. OFF.

December, 1942; Page 979

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monthly; subscriptions \$5 a year. Entered as second-class matter Feb. 7, 1921, at the post office at Cleveland, Ohio, under the

A **TOUGH ALLOY** *for a* **HOT JOB**



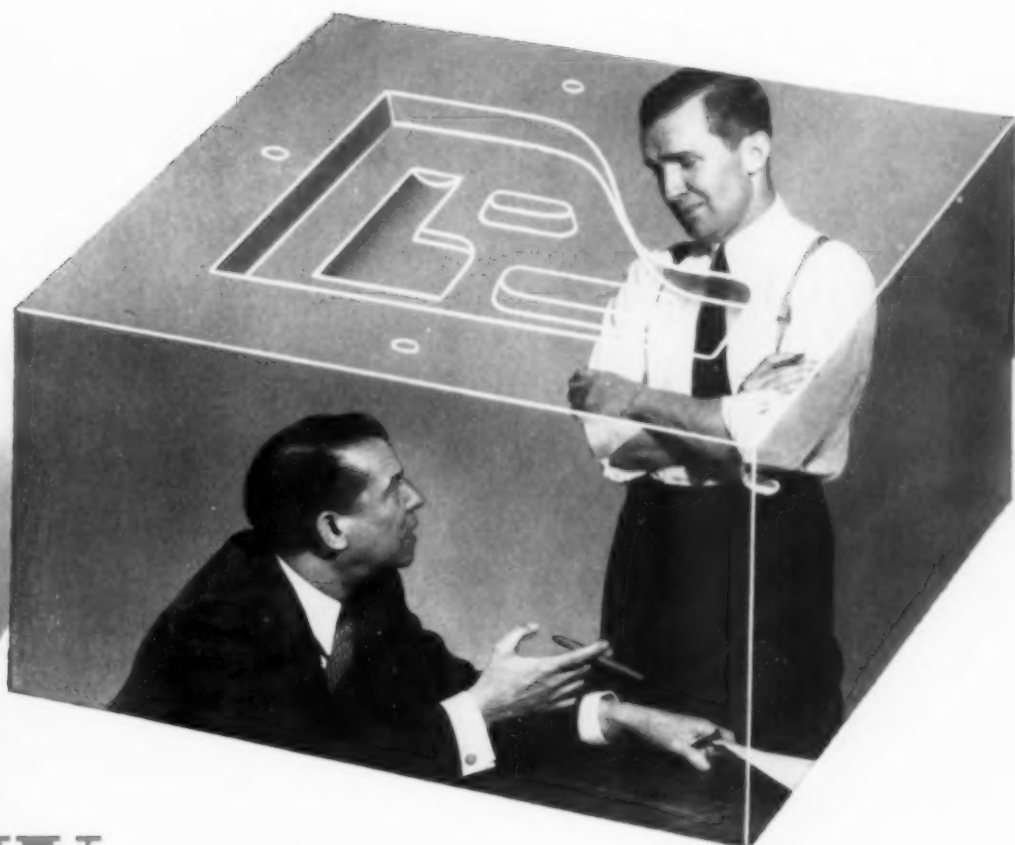
WHEN it comes to good alloy castings, there is more to it than composition. The rest of it is design, experience, and foundry skill. Into our Alloy 502, go all these requirements. It contains 35 nickel and (please note) 18.5 chromium, and we've been making it for thirty years.

All our melting is by high frequency induction which assures uniform composition. . . . So, for all your "hot" jobs, you should investigate Alloy 502. It's available cast or wrought. Tell us your problem—we think we can help. . . . Hoskins Manufacturing Co., Detroit, Michigan.

HOSKINS PRODUCTS

ELECTRIC HEAT TREATING FURNACES • HEATING ELEMENT ALLOYS • THERMOCOUPLE AND LEAD WIRE • PYROMETERS • WELDING WIRE • HEAT RESISTANT CASTINGS • ENAMELING FIXTURES • SPARK PLUG ELECTRODE WIRE • SPECIAL ALLOYS OF NICKEL • PROTECTION TUBES





"We need more production... per die"
... and LATROBE helped increase output as much as 300%

This is a war of
METALS

It calls for conservation and replacement of critical metals. It presents new problems in selection, application and handling of tool steels. You'll find Latrobe Metallurgical Service a vital war-time aid in such cases...we'll gladly help you without obligation!

A large user of die steels, had been using a steel of a particular analysis which for years had given good performance. Yet production had to be increased!

Latrobe's trained metallurgical staff was called upon to provide a solution. Many factors had to be considered, such as toughness,

deformation in heat treatment, ductility possible with high hardness, etc. The answer required diligent application, exhaustive study, patient research.

But the result proved the worth of *Latrobe Metallurgical Service*, for production per die was increased as much as 300%.

LATROBE

Metallurgical Service

Latrobe **ELECTRIC STEEL COMPANY**

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2 ways to help win the war

1

Save Scrap

Your help is needed to supply the millions of tons of scrap iron and steel necessary to speed vital production and help win the war. Collect the scrap from your plant NOW—then rush it to Steel Producers through regular Scrap Dealers. And keep it moving!

2

Conserve Strategic Alloying Elements

The use of N-A-X 9100 Series of alloy steels conserves critical alloying elements—because in this versatile steel all strategic elements are held to an absolute minimum. N-A-X 9100 Series is supplied in two general grades, with and without molybdenum, all other components of this analysis being held constant.

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Detroit, Michigan

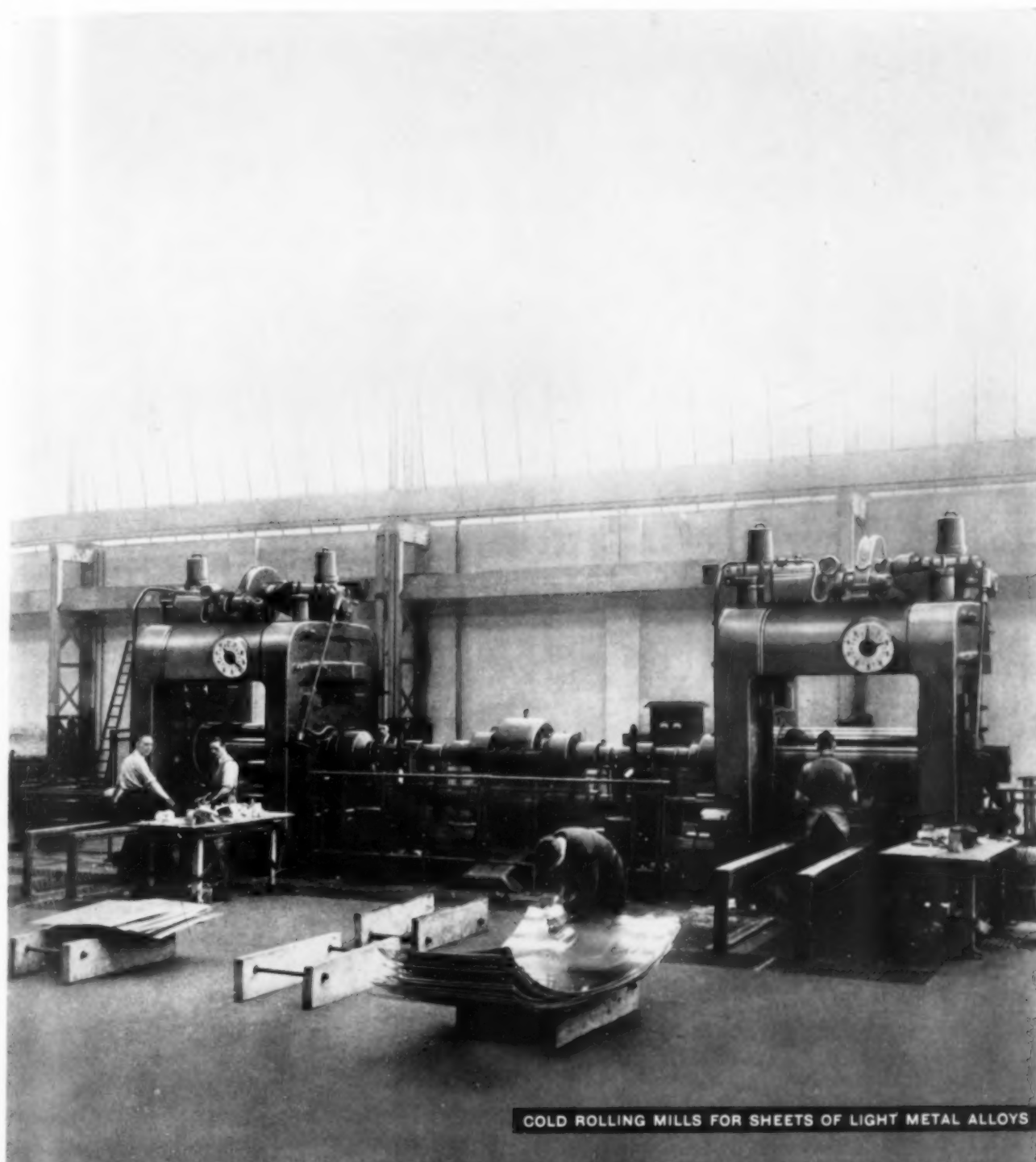
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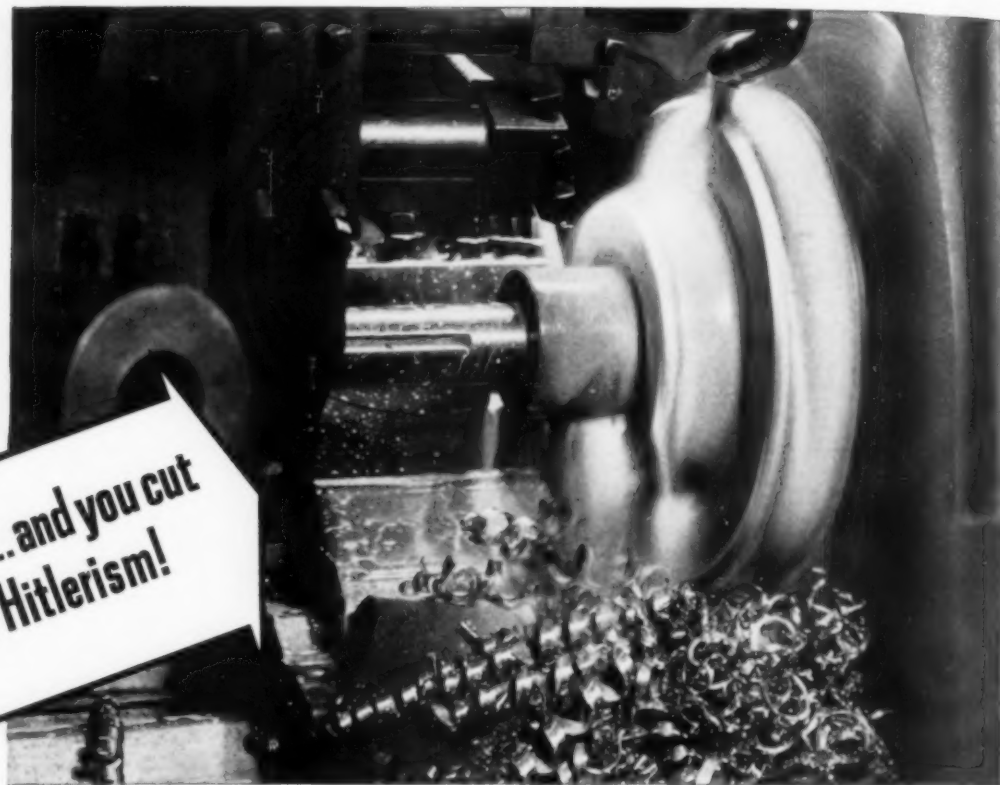
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the days of Hitlerism!



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Anything that can be done to speed up production—*must be done*.

And one thing you can and should do is to consult with an experienced Cities Service lubrication engineer for ways and means of speeding up production and improving finish and tool life.

There is no cost nor obligation to you for

this consultation. Just phone, write or wire your nearest Cities Service office.

Cities Service cutting oils have stood up to the toughest tests of day-to-day shop operation. That's why more and more wartime producers of urgently needed materials are relying on Cities Service to make every second—and every dollar—count!

OIL IS AMMUNITION—USE IT WISELY!



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ARKANSAS FUEL OIL COMPANY
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A copy of a booklet useful to all cutting fluid users will be sent on receipt of the coupon below

Please send me your booklet, "Metal Cutting Lubrication." A.M.

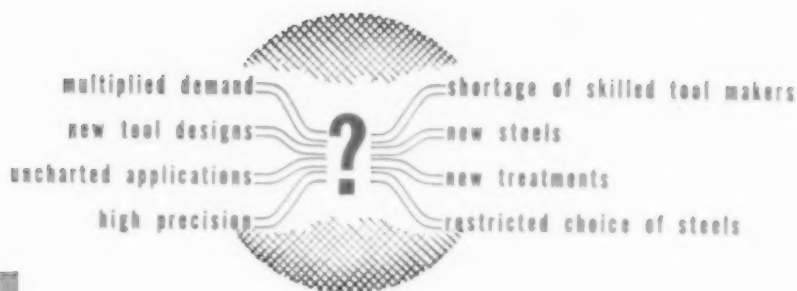
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Firm Name _____

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A LUBRICANT FOR EVERY INDUSTRIAL NEED



Aid on wartime tool steel problems

Top speed war production demands TOOLS — *more* tools than dreamed of in peace time — *new kinds* of tools for new war time jobs. The tool industry is tackling this tremendous task short of skilled tool makers and restricted by shortages in their choice of steels.

Solutions to these new problems are being worked out every day by the tool industry. Frankly, we don't have all the answers but our contacts with American tool makers determined to win this war puts us in a position to assist you in finding solutions to some of the particular problems that may be facing you.

On your problems of steel selection and treatment of tool steels, we would be very glad to have you get in touch with us. For your convenience, we are listing below the addresses of our district offices.

COPPERWELD STEEL COMPANY • WARREN, OHIO



BUFFALO	1127 Liberty Bank Building	Washington 7283
CHICAGO	122 S. Michigan Avenue	Harrison 1411
CLEVELAND	1158 Union Commerce Building	Cherry 1326
DETROIT	7-251 General Motors Building	Trinity 1-1760
NEW YORK	117 Liberty Street	Cortlandt 7-8314



GIVE US MORE TANKS!

That is where welding came into its own—for precious hours on the assembly line then could be saved—to produce more tanks with the same number of men on the same line.

And that is where the new welding electrode developed exclusively by PAGE for welding armor plate went to work—after it had met successfully all ballistic tests on plates submitted to the Army Ordnance Department by the tank manufacturers.

Chalk that up as another important contribution by PAGE that will be at the service of industry when Victory brings peace.

PAGE STEEL AND WIRE DIVISION

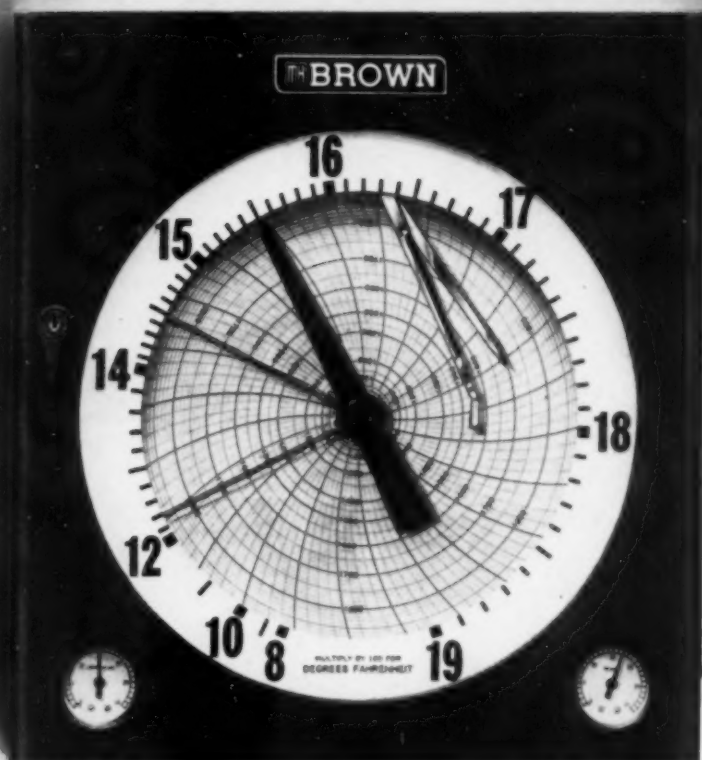
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In Business for Your Safety

AMERICAN CHAIN & CABLE COMPANY, INC. BRIDGEPORT, CONNECTICUT

The Instrument of Tomorrow



WORKING
Today
IN THE WAR
INDUSTRIES



The Brown "Continuous Balance" Air-o-Line Potentiometer Controller is the culmination of more than three-quarters of a century of experience in building industrial measurement and control instruments.

The experience of the past combined with the demands of today have resulted in a new potentiometer air-operated controller that will meet the needs of many future years.

In this radically new potentiometer controller a "Continuous Balance" Unit takes the place of the galvanometer used in the conventional mechanical-type potentiometer employing a periodic or cyclic mechanism.

It is the only potentiometer-type instrument in which the air control flapper mechanism is *instantly* positioned in response to temperature changes.

The "Continuous Balance" measuring system makes it possible to take full advantage of thermocouple responsiveness. Positive control action is assured by the

well-known, dependable Brown Air-o-Line Control Unit, thousands of which are in service throughout industry.

The Brown Circular Chart Air-o-Line Potentiometer Controller brings to industry, for the first time, the ideal synchronization of measurement and control for temperature processes.

BULLETIN SENT ON REQUEST

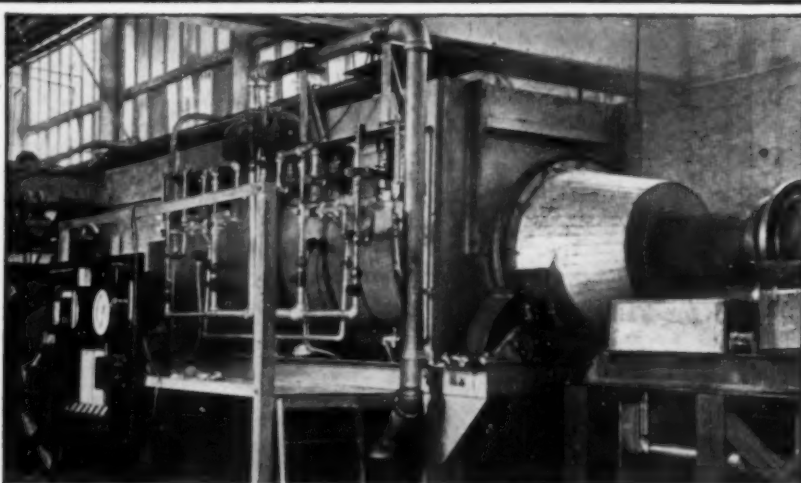
Outstanding features such as: Control Unit—Throttling Range Dial—Automatic Reset Dial—Booster Pilot Valve—Control Index Knob—Direct and Reverse Action—Compression Type Fittings—Control By-Pass Panel—Balancing Motor—Slide Wire—Pen Arm Release—Chassis—are fully described in Bulletin 15-4. Write for it.



BROWN

"Continuous Balance" POTENTIOMETER CONTROLLER

THE BROWN INSTRUMENT COMPANY, 4503 WAYNE AVENUE, PHILADELPHIA, PENNSYLVANIA
DIVISION OF MINNEAPOLIS-HONEYWELL REGULATOR CO.
MINNEAPOLIS, MINNESOTA AND 119 PETER STREET, TORONTO, CANADA
Wadsworth Road, Perivale; Middlesex, England
Nybrokajen 7, Stockholm, Sweden



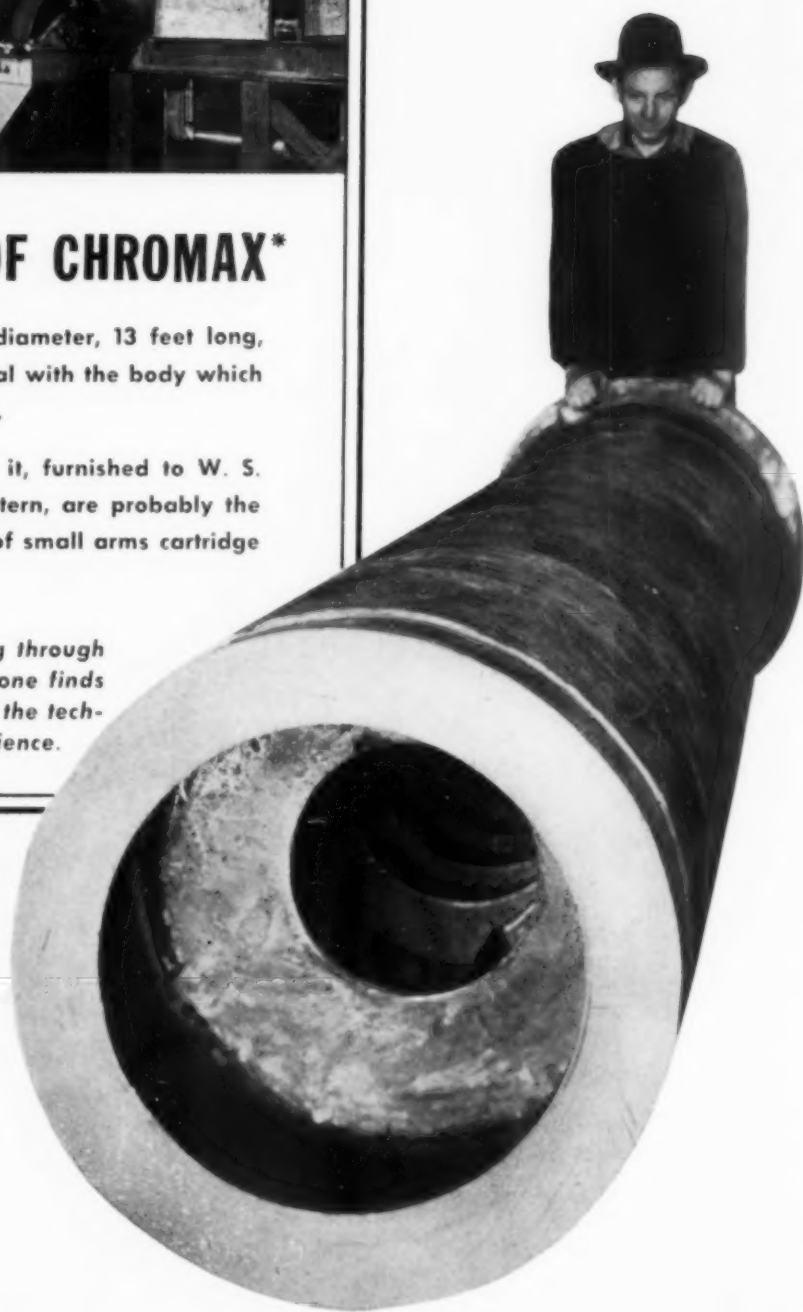
4,500 POUNDS OF CHROMAX*

Yes a 4,500 pound retort 26" diameter, 13 feet long, with a 6" high spiral cast integral with the body which by rotating propels work through.

This retort and many more like it, furnished to W. S. Rockwell Co. from the same pattern, are probably the biggest factor in the production of small arms cartridge cases.

Just one of the many jobs going through the Driver-Harris foundry where one finds both the productive facilities and the technique gained from years of experience.

*TRADE MARK REG. U.S. PAT. OFF.



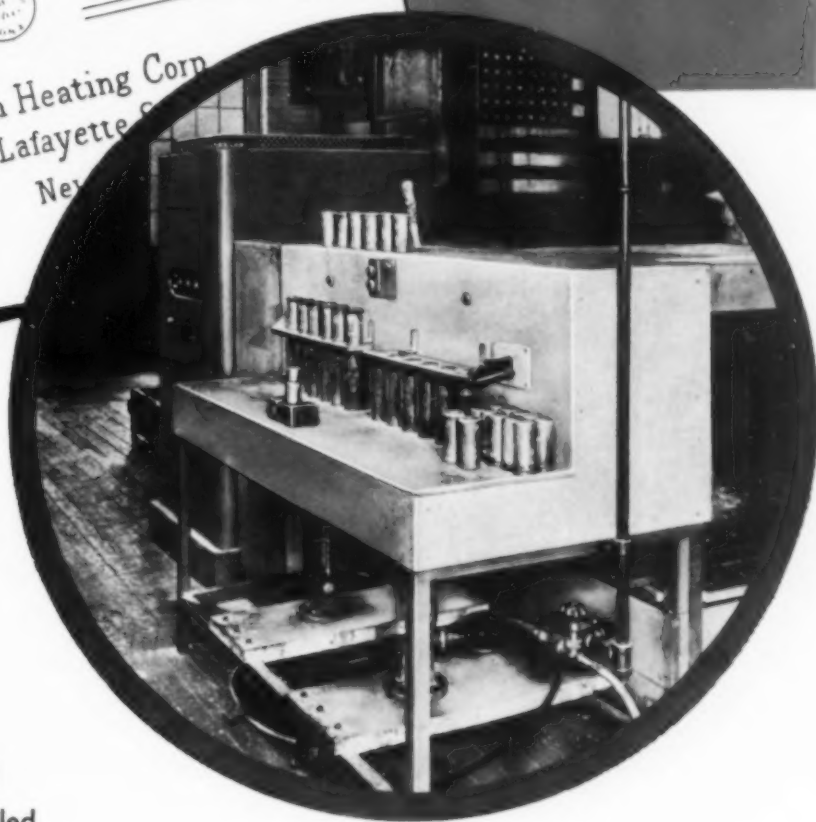
DRIVER-HARRIS *Company*

HARRISON, NEW JERSEY

Metal Progress; Page 988

Some call it— *Production* Thermonic Induction Heating

Production Heating Corp
389 Lafayette St
New York City



In numerous cases, the introduction of THERMONIC Induction Heating has removed the time-wasting link from the production line chain, and has speeded it up to mass production requirements. The photograph at the right shows a typical THERMONIC production setup, installed at the [redacted] plant, turning out 15,000 brazes on [redacted] in a 20 hour day. Plants from coast to coast are using THERMONIC equipment in order to keep up on their production schedules. Why not use the wealth of "production" experience possessed by the THERMONIC Research and Development Engineering Staff to solve your next production problem?

A series of Data Sheets completely covering the subject of Induction Heating will be issued monthly. Nos. 1, 2, 3 and 4 are ready for you. Write to Department A on your company letterhead.

INDUCTION HEATING CORPORATION
Designers • Builders • Of Thermonic Heat Treating Equipment
389 LAFAYETTE STREET, NEW YORK CITY, N. Y.

INDUSTRY IS ON AN EIGHT-DAY WEEK



Seven days a week America is doing one of the greatest jobs of production the world has ever known. We are living with one part of that job here at Alcoa, where over seventy thousand men and women are producing Aluminum in quantities that were mere fantasy yesterday.

But there's an eighth day tucked in among the few open spaces in the seven-day week. Engineers are able to squeeze in some important Imagineering about post-war products—planning that will help convert war jobs into peace jobs.

For instance:

Imagine what 1,000 pounds less weight in the automobile of the future would mean in performance, gas economy and tire life. Then engineer it down

to the realization that 1,000 pounds *can* be taken off by using, say, 500 pounds of Aluminum per car.

Now translate possibilities such as these into your own business.

Aluminum costs less today. New methods, techniques, processes, and new forms of metal coming out of the war effort will all be available for the as-yet-untold possibilities in tomorrow's peacetime products and peacetime services.

Our eighth day is devoted to helping Imagineers throughout industry use the potentialities of Alcoa Aluminum in bettering the new ideas they are dreaming up. ALUMINUM COMPANY OF AMERICA, 2101 Gulf Building, Pittsburgh, Pennsylvania.



ALCOA ALUMINUM



Metal Progress; Page 990

MAHR

ENGINEERS • DESIGNERS • MANUFACTURERS
ALL EQUIPMENT FOR METAL HEATING

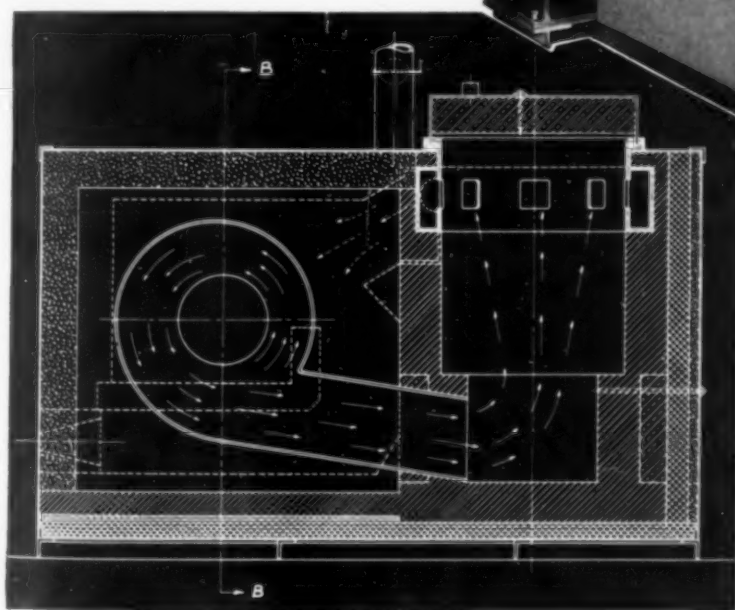
Recirculating-Cylindrical HEAT PROCESSING UNIT

*for air drawing at 1250°F**

Here's an all-purpose MAHR heat processing unit with great flexibility of use. For heat application to ferrous or non-ferrous metals, also plastics—it handles a wide variety of small parts for war production—and will be equally adaptable later to the needs of peace time manufacturing. It has a quick heat-up and remarkably uniform temperature continuously during the treating period. This MAHR unit is very economical because of its efficient recirculating design and thorough insulation. MAHR'S quarter century of experience assures its dependable quality.

**and for other
heating processes
at intermediate
temperatures*

LONGITUDINAL CROSS-SECTION VIEW
showing arrangement of blower, ducts, and
cylindrical heating chamber, with collector
ring at top proportioned for uniformly even
flow of air back to heating chamber for
recirculation.



Gas or Oil Fired with manual control as standard. Temperature control and flame failure safety equipment available at extra cost.

Construction is of mild steel casing with removable top for easy access to inside.

Self-Sealing Lid for heating chamber provides a tightly sealed joint when closed, and also locks itself in position when open. It is an extremely easy working mechanism.

Fan, Shaft and Duct are of special heat resistant alloy steel. Fan on shaft cools shaft bearing.

Lining is best grade refractory. Cover is lined with castable refractory insulation. Treating chamber is walled with fire brick.

Insulation as noted in cross section is brick and block insulation that effectively keeps the heat within the unit.

Made in 9 sizes — Cylindrical basket sizes for treating chamber range in diameter from 12" to 48" and in depth from 16" to 60". Special sizes can be made.

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Call in a
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he can help you
on any heat treat-
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Wire, write or
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★ Save ALL ★
★ your scrap! ★
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★★★★★★★
★ Buy MORE ★
★ War Bonds ★
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Diesel Power

DEPENDS ON **CAST STEEL**

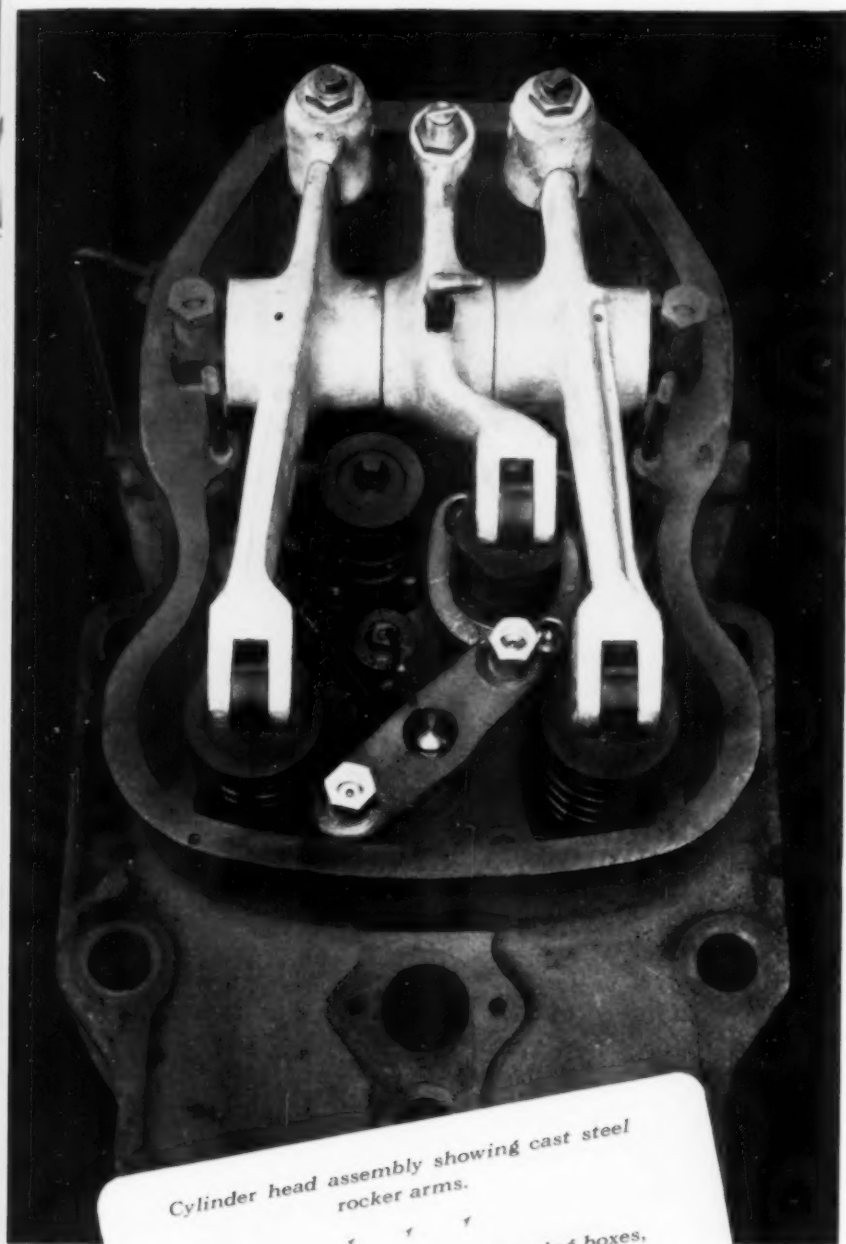
Vital parts of the Diesel engines that drive trains and ships and trucks are steel castings. These rarely-seen arms and gears and valves and housings deliver unfailing production of power, maintaining their precision fit, and their resistance to high pressure, wear, heat, vibration and fatigue.

Wherever tough conditions must be met by metals, steel castings are giving faultless performance.

From small parts precisely shaped to close tolerances, to large structural members weighing tons, castings are the most economical means of securing the many desirable properties of steel.

They help to speed up manufacture—to save time in finishing and assembly. Often they are complicated shapes that could not be economically produced by any other method. They afford almost infinite variety of mechanical properties readily obtainable by using different heat treatments and alloy additions. They may be perfectly welded in composite structures.

If you'd like to have your own products analyzed, to see where steel castings can make them better or less costly to build, consult your own foundryman, or write to Steel Founders' Society, 920 Midland Bldg., Cleveland. No obligation of course.



Cylinder head assembly showing cast steel rocker arms.



Cast Steel supercharger arm, bearing boxes, housing, gear hub and gears.

MODERNIZE AND IMPROVE YOUR PRODUCT WITH

STEEL CASTINGS

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ARMY AIR FORCES
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OFFICE OF THE DISTRICT DISTRICT
CENTRAL PROCUREMENT DISTRICT
8505 W. WARREN AVE.
DETROIT, MICH.

July 13, 1942

PRODUCTION SECTION
CENTRAL PROCUREMENT DISTRICT
MANUFACTURERS' LETTER NO. 10
CHICAGO AREA OFFICE

CHICAGO AREA OFFICE

SUBJECT: Cemented Tungsten Carbide for Cutting Tools

1. The following is quoted from memorandum, dated June 10, 1942, from the War Department, Headquarters. Services of Supply, Washington, D.C.:

"In the interest of conservation of critical alloys and of increased production, attention is directed to the following stated advantages of cemented tungsten carbide tools . . .

"a. One pound of tungsten in the form of cemented tungsten carbide for cutting tools will do the work of 70 to 100 pounds of tungsten in high speed tool steel. Furthermore, its use eliminates substantial amounts of chromium and vanadium which are considered necessary components of practically all high speed tool steel.

"b. Cemented tungsten carbide functions satisfactorily on almost all types of lathes and boring machines, particularly those of the sturdier construction. This is said to include all such machine tools manufactured in the last five years.

"c. Cemented tungsten carbide works efficiently on all steels above approximately .30 carbon and is effective up to 500 brinell or more.

"d. Cemented tungsten carbide will give two or three times the production of high speed tool steel in those operations to which its use is adapted over a given run will require about one-fifth the number of grinds that standard high speed tool steel will require."

"e. Cemented tungsten carbide is forwarded by direct mail, Wright Field letter, EAZ-ar-72-2, (July 3, 1942).

2. This information should be directed to the AAP, Chicago, Illinois, Attention:

3. Any requests for further information should be directed to the AAP, Chicago Area Office, 20 N. Wacker Drive, Chicago, Illinois, Attention:

Production Section.
for the District Supervisor:

HARLEY S. JONES
Lt. Colonel, Army Air Forces
Technical Executive

NOTE:
In the reproduction of the above letter by Firth-Sterling, it is to be understood that it does not imply the WAR DEPARTMENT'S indorsement of any company's products.



YOU CAN DO IT WITH

FIRTH

TUNGSTEN - TITANIUM CARBIDES

FOR STEEL CUTTING

T-04* Universal grade for heavy duty, interrupted cuts, and coarse feeds, on older machines.

TA* General-purpose grade for cutting steels under "average" conditions.

T-16* The grade for fine, extremely fast machining of steel.

T-31* Hardest, wear-resistant, premium grade for precision boring, etc.

*** TITANIUM** in these FIRTHITE grades makes possible better, faster, cheaper cutting of steel and at the same time permits tool prices comparable with those for high-speed steel. These FIRTHITE grades are made under one or more of the following patents on **TITANIUM** Carbides: 1,925,910; 2,023,413; 2,246,387; 2,265,010; Re. 22,073; Re. 22,074; Re. 22,166; Re. 22,207.

Firth-Sterling

STEEL COMPANY

Offices: McKEESPORT, PA. NEW YORK - HARTFORD - PHILADELPHIA
CLEVELAND - DAYTON - DETROIT - CHICAGO - LOS ANGELES



CHRISTMAS
GREETINGS

from

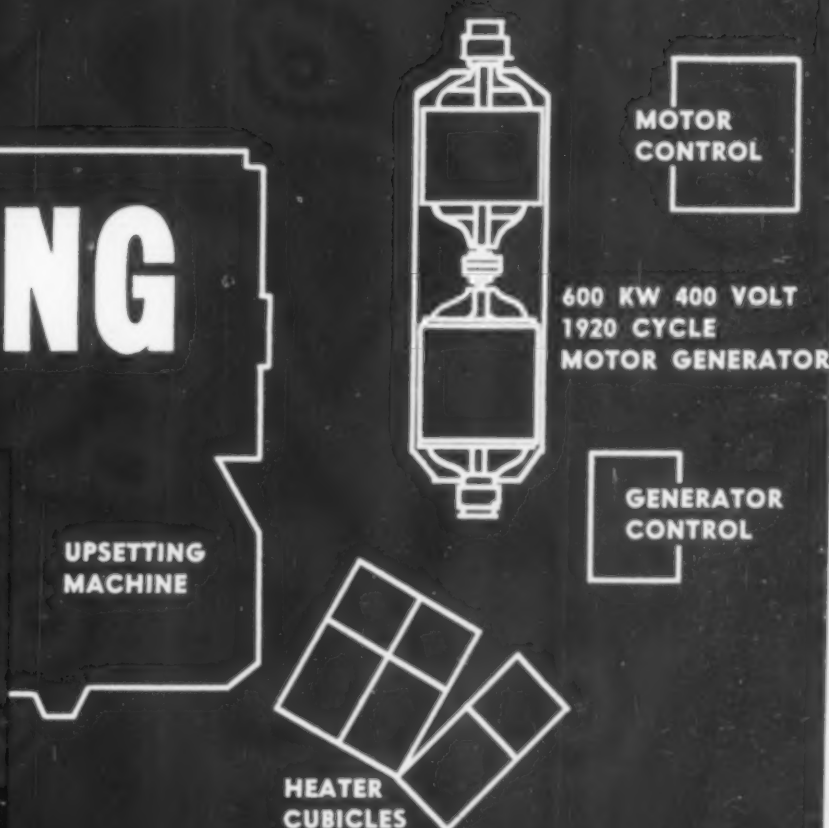
The Employees of
THE PRESSED STEEL COMPANY
Wilkes-Barre, Pennsylvania

Manufacturers of

Carburizing and Annealing Boxes, Thermocouple Protection Tubes,
Seamless Steel Cylinder Caps, Seamless Steel Neck Rings, Welded
Alloy Tubing for High Temperature and Corrosive Application,
Radiant Tubes, Inner Covers, and Base Sheaths for Steel Mills.



UPSETTING



20,000 A DAY!

and later on-

Practically all of the equipment in this installation will be readily convertible to automobile forgings, as small as 1" in diameter, when the emergency is over.

It will be possible to heat any section of the bar by changing the taps on the heater.

In fact, about 80 per cent of all investments now being made in Ajax heating or melting furnaces can be converted to produce new economies in peace-time efforts.

With line production "floating" on conveyors and high frequency heating for forging, 75 and 105 mm shells are put through this plant, from bar stock to packaged shells, at the rate of 20,000 per day.

Ajax-Northrup high frequency heating was chosen because of the short time cycle, small space required, low unit heating cost, freedom from scale and therefore longer life of the dies and less down time for changing tools.

The layout shown above with three heater cubicles, for instance, heats one 105 mm billet every 40 seconds. Five heaters turn out one 75 mm shell every 23 seconds.

Time of heating is automatic. On account of the small heat loss, operators experience little or no discomfort, and the synchronous motors that operate the high frequency generator are of material value in improving the power factor of the entire plant.

If you are considering a government contract, we will send you a reprint of an article giving details. We suggest that you become familiar with the effect that high frequency will have on civilian production as indicated at the left.



AJAX HIGH FREQUENCY FURNACES

NORTHROP AJAX ELECTROTHERMIC CORPORATION, AJAX PARK, TRENTON, N.J.

ASSOCIATE COMPANIES: THE AJAX METAL CO. Non-Ferrous Ingot Metal for foundry use.
AJAX ELECTRIC FURNACE CORPORATION. Ajax-Wyatt Induction Furnaces for melting.
AJAXELECTRIC CO., Inc. Ajax-Hultgren Salt Bath Furnace and Resistance Type Electric Furnaces.

Do you machine aluminum?

**Gulf Cut-Aid will help you get higher
production speeds, better finishes
and longer tool life!**

IN plant after plant, Gulf Cut-Aid is demonstrating its superiority as a cutting fluid for aluminum. Here are typical results with this revolutionary new Gulf product:

1. *Operation*—turning aluminum castings, $\frac{1}{8}$ " cut
Result, using
Gulf Cut-Aid—20% increase in production, 75% better finish (est.), longer tool life
2. *Operation*—tapping a $\frac{3}{4}$ " diameter hole in a $\frac{1}{4}$ " thick instrument cover plate



Undercutting the valve seat on an aluminum alloy cylinder head in the plant of a prominent aircraft engine manufacturer.

Problem—1 part in 20 rejected due to cracking
Result, using

Gulf Cut-Aid—over 500 cover plates tapped without a reject.

In addition to its function as the ideal cutting fluid for aluminum, Gulf Cut-Aid has another important function — it is an effective energizer for other cutting oils, regardless of type or viscosity. Blended in varying proportions depending upon the various requirements of the job, the use of Gulf Cut-Aid with other cutting oils results in improved finish or longer tool life, or both.

Call in a Gulf service engineer today and let him demonstrate — in your plant — how Gulf Cut-Aid and other Gulf quality cutting oils can help improve your machining practice. Gulf Oil Corporation, Gulf Refining Company, Gulf Building, Pittsburgh, Pennsylvania.



Gulf Oil Corporation • Gulf Refining Company
3800 Gulf Building, Pittsburgh, Pa.

MP

Please send me, without obligation, a copy of the new booklet, "Gulf Cutting Oils," which includes a 24-page Machining Guide.

Company.....

Name.....

Title.....

Address.....

DOW



The weight of our planes is materially lowered by the use of magnesium which Dow is extracting in vast quantities from the waters of the sea. Fighting aircraft fly faster and farther by virtue of this strategic weight-saving metal. The social effect of wide-scale applications of magnesium will be fully realized only when Victory releases it for unrestricted peacetime uses.

THE DOW CHEMICAL COMPANY, MIDLAND, MICHIGAN



MAGNESIUM

The Lightest Structural Metal . . . A Full Third Lighter Than Any Other in Common Use

December, 1942; Page 997

THE PROPERTIES OF LEAD

Plasticity, Malleability and Pliability

PLASTICITY • The ease with which thin tubes of lead can be squeezed or folded by hand is responsible for its ever increasing use in the manufacture of collapsible tubes. Such tubes are usually made of about 98% lead and 2% antimony to stiffen and strengthen the walls. Lead collapsible tubes offer a number of other advantages. Among them are immunity to breakage; savings in freight and space; and protecting those products upon which moisture, air or light rays have a deteriorating effect.

MALLEABILITY • The major application of lead, because of its malleability and plasticity, combined with its high corrosion resistance and comparatively low cost, is in the manufacture of lead foil. A comparison of these properties of lead with other common non-ferrous metals is given in the table at the right:

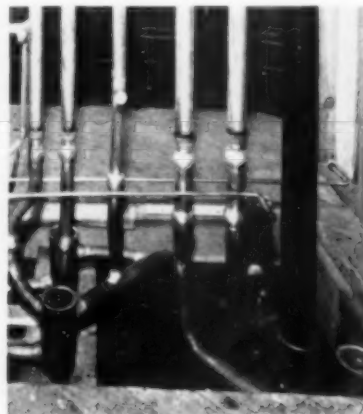
	Resistance to Equivalent Deformation lbs. per sq. in.	Order of Malleability (Liddell)	Plasticity
Lead	4,500	3	2
Tin	7,000	2	3
Aluminum	25,500	1	1
Zinc	29,000	4	4

Lead foil is impermeable to moisture and the passage of light rays; it will not impart the slightest trace of taste or smell to the commodity which it protects. The foil industry has used as much as 39,000 tons of lead in a single year.

PLIABILITY • The pliability of lead is an important contributory factor in the wide use of the metal for pipe, tubing and cable sheathing. This property allows almost any length of lead pipe to be reeved through holes cut in walls or beams, making fewer joints necessary; it also permits lead pipe to be bent to the necessary angles, eliminating many elbows and nipples required by more rigid materials. The pliability of lead also permits expansion and contraction of the pipe due to changes in temperature, as well as any distortion that might occur because of uneven settling or vibration in the ground.



Tea protected with lead foil. One package is torn open showing the foil lining, which is .0015 in. thick.



Lead work installed on the Silver Bow Housing project at Butte, Montana.



Collapsible lead tubes are well adapted to packaging shoe polish and innumerable other products.

ST. JOSEPH LEAD COMPANY

250 PARK AVENUE • NEW YORK • ELdorado 5-3200

THE LARGEST PRODUCER OF LEAD IN THE UNITED STATES

What Zirconium Does For Steel...

AMONG the many "Electromet" ferro-alloys are a number of special deoxidizers. Each has particular value for certain war production jobs. One of the most powerful is Zirconium. Not only does it effectively remove oxygen, but it also reacts with nitrogen and sulphur producing a fine-grained steel free from harmful inclusions. Alloying quantities of Zirconium (up to 0.15 per cent) are essential in the balanced composition of certain of the low-alloy, high-tensile engineering steels. In tool steels it is reported that Zirconium improves the hot-working properties, improves the surface, reduces notch sensitivity, and lessens tendencies toward cracking during heat treatment. It increases the impact values of high-phosphorus Bessemer steels and gives better hot-working properties in free-machining high-sulphur steels. Zirconium is also used for reducing porosity in green-sand castings and for reducing age-hardening in deep-drawing steels.

For most effective results Zirconium is added in combination with silicon. We make two Zirconium alloys . . . one containing 12 to 14 per cent Zirconium and 39 to 43 per cent silicon; the other, 35 to 40 per cent Zirconium with 47 to 52 per cent silicon. If these Zirconium alloys can help in your war production job, one of our metallurgists will be glad to call and discuss them with you.

ELECTRO METALLURGICAL COMPANY

Unit of Union Carbide and Carbon Corporation

30 East 42nd Street



New York, N. Y.

Items of Interest about other "Electromet" Ferro-Alloys

For Cleaner Steel, Make a Final Addition of Calcium-Manganese-Silicon — Calcium-manganese-silicon, used as a final



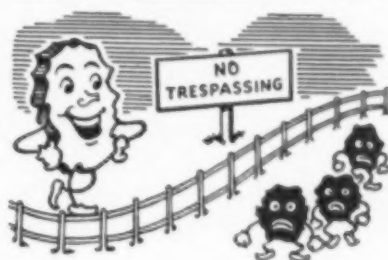
alloy addition to steel, produces a cleaner, coarse-grained steel with deep-hardening properties. Long commercial use of this combination alloy has proved its merits for this purpose. Calcium-manganese-silicon is also being successfully used to deoxidize all types of stainless steel, high-speed tool steels, and special steels subject to transverse testing.

Columbium Improves 4 to 6 Per Cent Chromium Steels —

When wrought 4 to 6 per cent chromium steels contain a small amount of columbium, they do not air-harden, and are more ductile even in the as-rolled state. They have higher creep strength, toughness and oxidation resistance at high temperatures. Welding and cutting are facilitated, and subsequent annealing is unnecessary.

The word "Electromet" is a registered trade-mark of Electro Metallurgical Company.

Medium-Carbon Ferromanganese Simplifies Production of Low-Carbon Steel — When medium-carbon ferromanganese is used in the production of steel, it is



not necessary to reduce the carbon in the molten metal to the extent required when higher-carbon grades are used. Oxidation of the bath is, therefore, much less severe. Valuable minutes of furnace time are saved. Refractory costs are reduced. Furnace output and yield are raised.

Low-Carbon Ferrochrome Produces Better Chromium Steel —

The lower carbon content of low-carbon ferrochrome as compared with high-carbon ferrochrome inhibits the formation and segregation of hard chromium carbide areas in chromium steel. A better, more uniform steel results.

Write for This Booklet — If you want more information about these and the many other "Electromet" ferro-alloys and metals, their use, and the service that goes with their purchase, write for this 24-page booklet entitled "Electromet Products and Service."

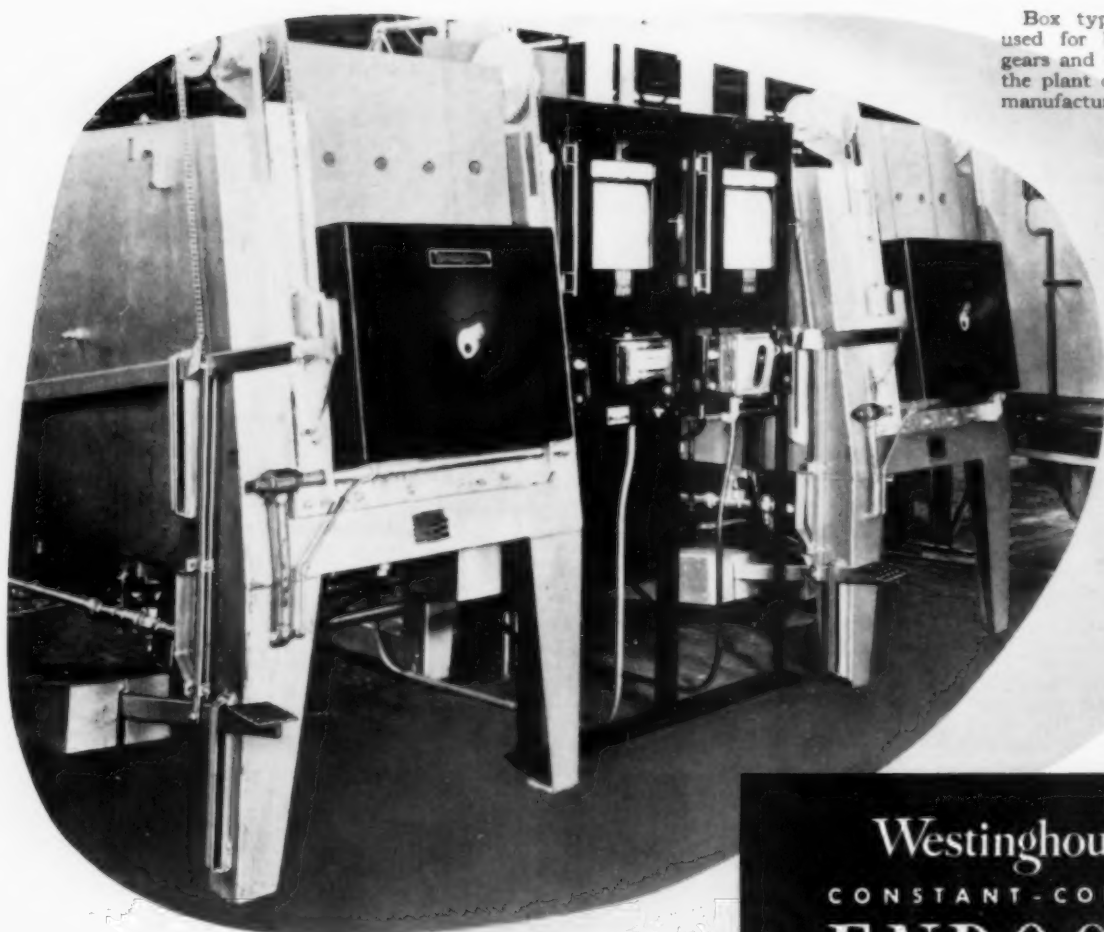


Electromet Trade-Mark Ferro-Alloys & Metals

Distributed through offices of Electro Metallurgical Sales Corporation in Birmingham, Chicago, Cleveland, Detroit, New York, Pittsburgh, and San Francisco. In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario.



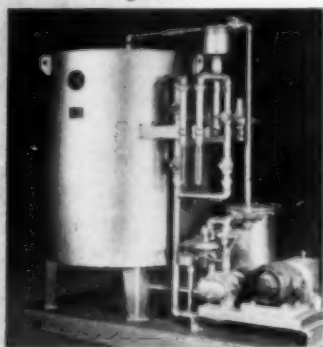
Box type Endogas Furnace used for batch production of gears and other engine parts in the plant of an airplane engine manufacturer.



**No charcoal to replace . . .
No carbon to remove . . . with**

Westinghouse
CONSTANT-CONTROL
ENDO GAS
ATMOSPHERE

Endogas atmosphere producing generator.



- **AUTOMATIC CARBON PRESSURE CONTROL**—Keeps output analysis constant and insures uniform atmospheres.
- **CLEAN-HARDENS WITHOUT "DECARB"**—Endogas prevents "soft skin" on all carbon and alloy carbon steels.
- **CUTS FINISHING COSTS**—Endogas eliminates expensive cleaning.
- **NO REPLACEMENTS OR REPACKING TO AFFECT OUTPUT**—Endogas generator consumes no charcoal, oil or coke. Replacements and cleaning are unnecessary.

Westinghouse ENDOGAS—the *constant-control* heat-treating atmosphere greatly simplifies continuous production in hardening applications.

ENDO GAS permits clean-hardening of any SAE steel without decarburization. It is derived directly from ordinary fuel gas. It consumes no charcoal, coke or other solid or liquid fuel which must be replaced. Westinghouse has developed *automatic carbon pressure control* which maintains a constant "carbon balance" with the steel to be treated. This enables clean-hardening any SAE steel parts on a continuous production basis without decarburization or carburization.

ENDO GAS is low in cost—requires no costly auxiliary equipment. It is available for use with a complete range of Westinghouse heat-treating equipment, including box type, pusher type and belt conveyor type furnaces. Ask for complete data. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., Dept. 7-N.

J-10235



COMPLETE HEAT-TREATING EQUIPMENT

ace
of
in
ine



Alloy War-Steel reports for its physical

OEM Photo by
Palmer, in an
Allegheny Ludlum Plant

TESTING is an integral part of production at Allegheny Ludlum mills. Thousands of dollars worth of amazingly accurate machinery are on the job in each mill, testing tensile strength, elastic limit, elongation and reduction of area—all the essential properties of each stainless grade—before it is shipped out for war production.

But after shipping, what? This Allegheny Stainless, made and tested to such rigid exactness, is a war material of the most vital sort. Every alloy in it stands high on the critical list. Is it being used as carefully as it was made? Are fabricators getting

the maximum number of products and parts from every ton, with the least possible loss in rejects, spoilage and other forms of waste? Are high alloys being used in places where lower alloys would suffice?

We urge you to check or re-check these questions against your own use of Allegheny Stainless, as a matter of vital concern in national conservation of materials. Especially do so if your plant, as a converted industry, is relatively un-used to the handling of stainless steel.

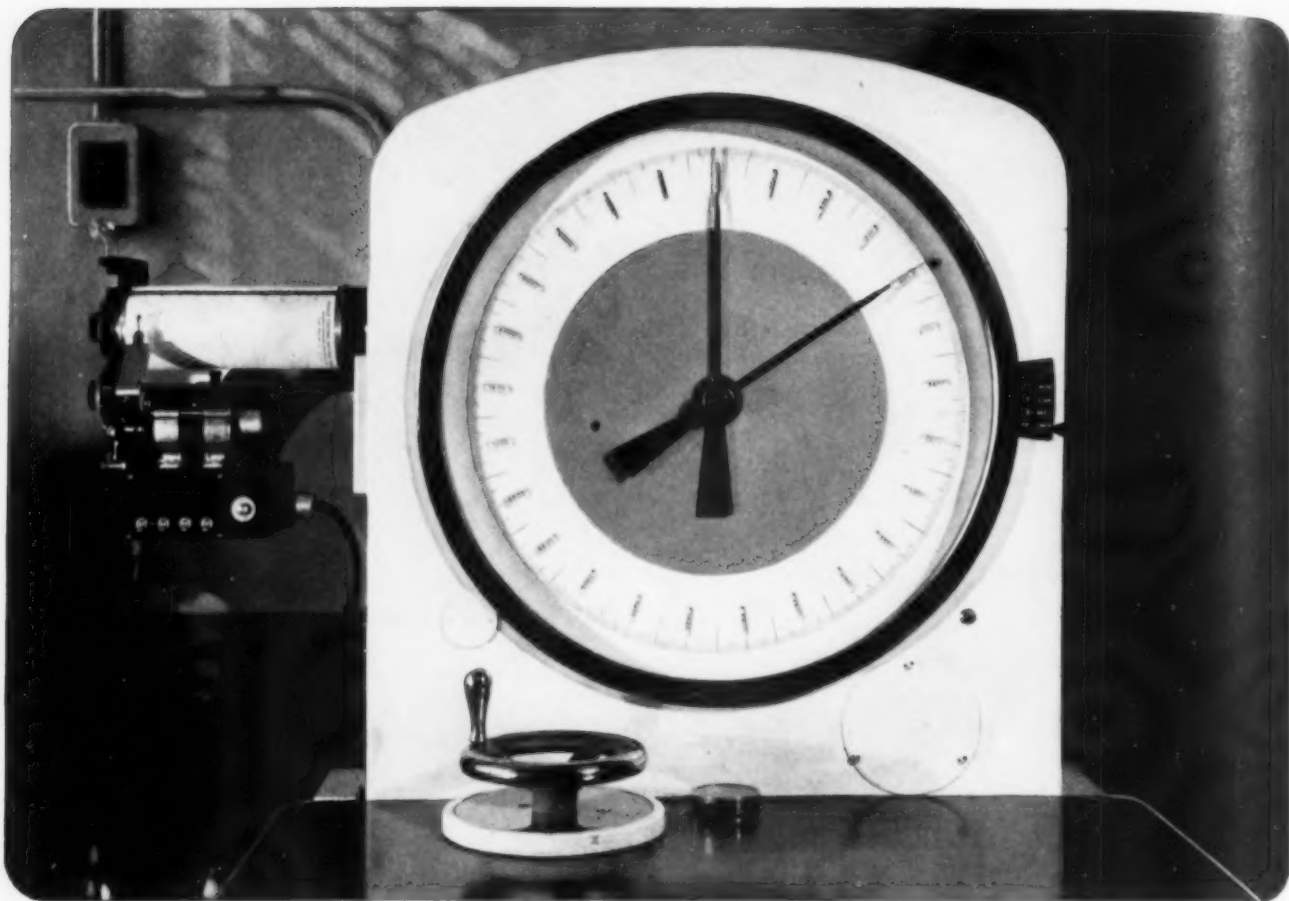
• We'll help you in any way possible to make the nation's supply of metals and alloys go farther.

Technical information, fabricating data, or the personal assistance of our Technical Staff, are yours on request.



**Allegheny Ludlum
STEEL CORPORATION**

GENERAL OFFICES: PITTSBURGH, PENNSYLVANIA

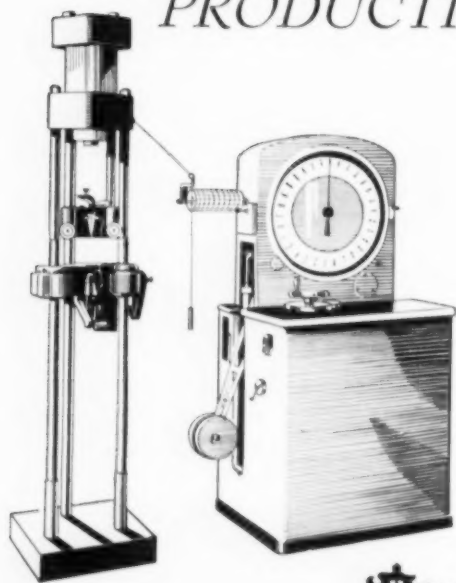


PRODUCTION TOOL...WORLD WAR II

TODAY, precision testing machines have become real production tools . . . tools that foretell success or failure for vital war materials.

Because the name RIEHLE stands for America's oldest manufacturers of testing machines, it has meant their logical acceptance from the first moment industry linked speed with accurate testing. Riehle Machines are making an important contribution in our present battle of production, proving repeatedly, in wartime as in peacetime, that . . . "ONE TEST IS WORTH A THOUSAND EXPERT OPINIONS."

Model P-3 (illustrated at left) Universal type machine expressly designed to speed up routine tension testing of wire, strips, sheets and light bars. One hand wheel control. Five scale ranges. Open gripping heads at convenient height. Capacities up to 30,000 pounds.



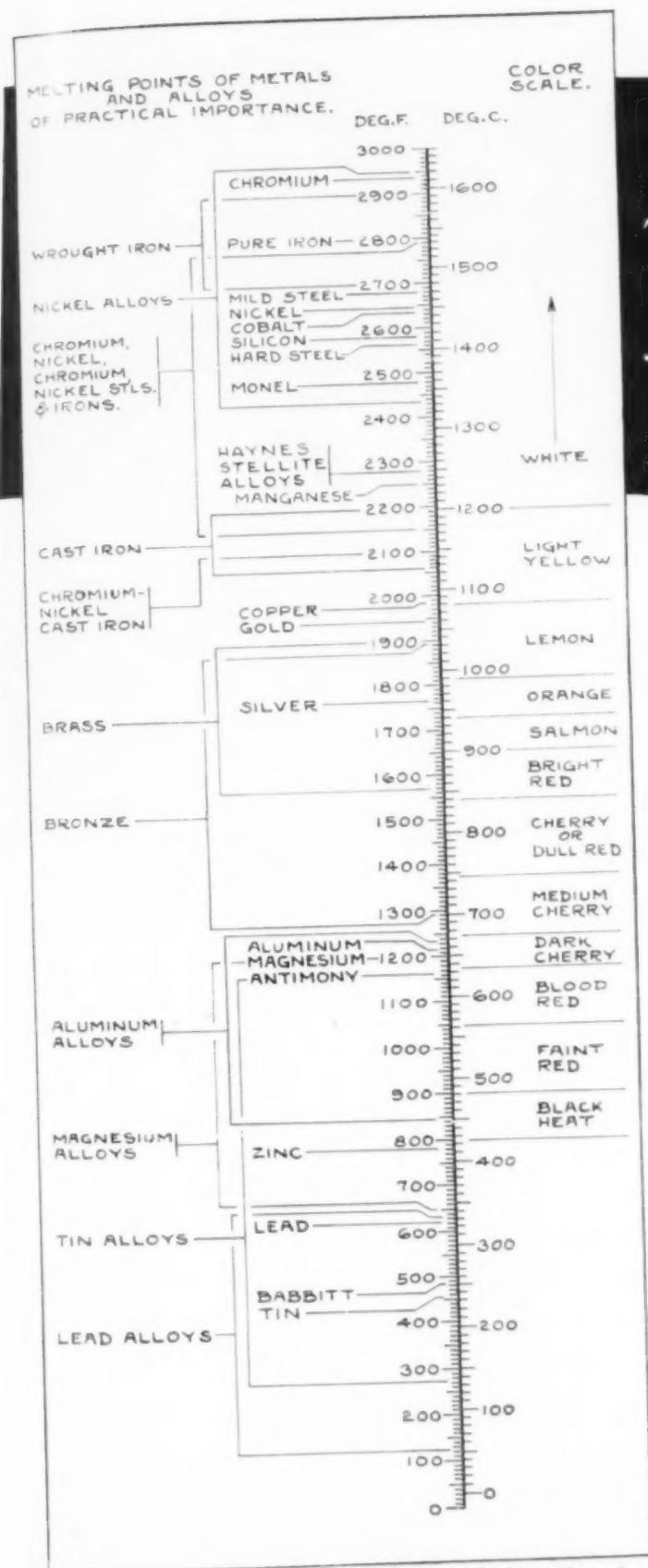
RIEHLE TESTING MACHINES

Division of American Machine and Metals, Inc., East Moline, Illinois

"One test is worth a thousand expert opinions"

UNIVERSAL MACHINES FOR TENSION, COMPRESSION AND TRANSVERSE TESTING • IMPACT TESTERS • VICKERS HARDNESS MACHINES • BRINELL HARDNESS TESTERS AND MEASURING INSTRUMENTS

Metal Progress; Page 1002



You can obtain reprints of this advertisement upon request.

Helpful TEMPERATURE DATA for Oxy-Acetylene Welding Operators

The chart at the left lists the melting points of various alloys and metals and also serves as a convenient means for computing conversion between Centigrade and Fahrenheit temperature scales. On the far right of the scale are shown the color designations that are commonly used in judging the temperatures of hot metal.

Melting Points

This chart should prove useful to all welding operators. For instance, reference to the chart, shows that aluminum and aluminum alloys, because of their low melting points, give little or no indication by change in color when they approach welding heat. On the other hand, the high melting point of wrought iron explains why considerably more heat is required to weld this metal than is required for cast iron.

Temperature Color Scale

Another use for the chart is in estimating the temperature by color. For instance, instructions may require that a part be preheated to 1,100 deg. F. before welding. Reference to the chart shows that the part, at 1,100 deg. F. would have a blood-red color. With a little experience, you can estimate this fairly closely by eye. The color scale is for observations made in a fairly dark place and without welding goggles. As the light increases, the color groups on the scale will apply to higher temperatures.



THE LINDE AIR PRODUCTS COMPANY

Unit of Union Carbide and Carbon Corporation



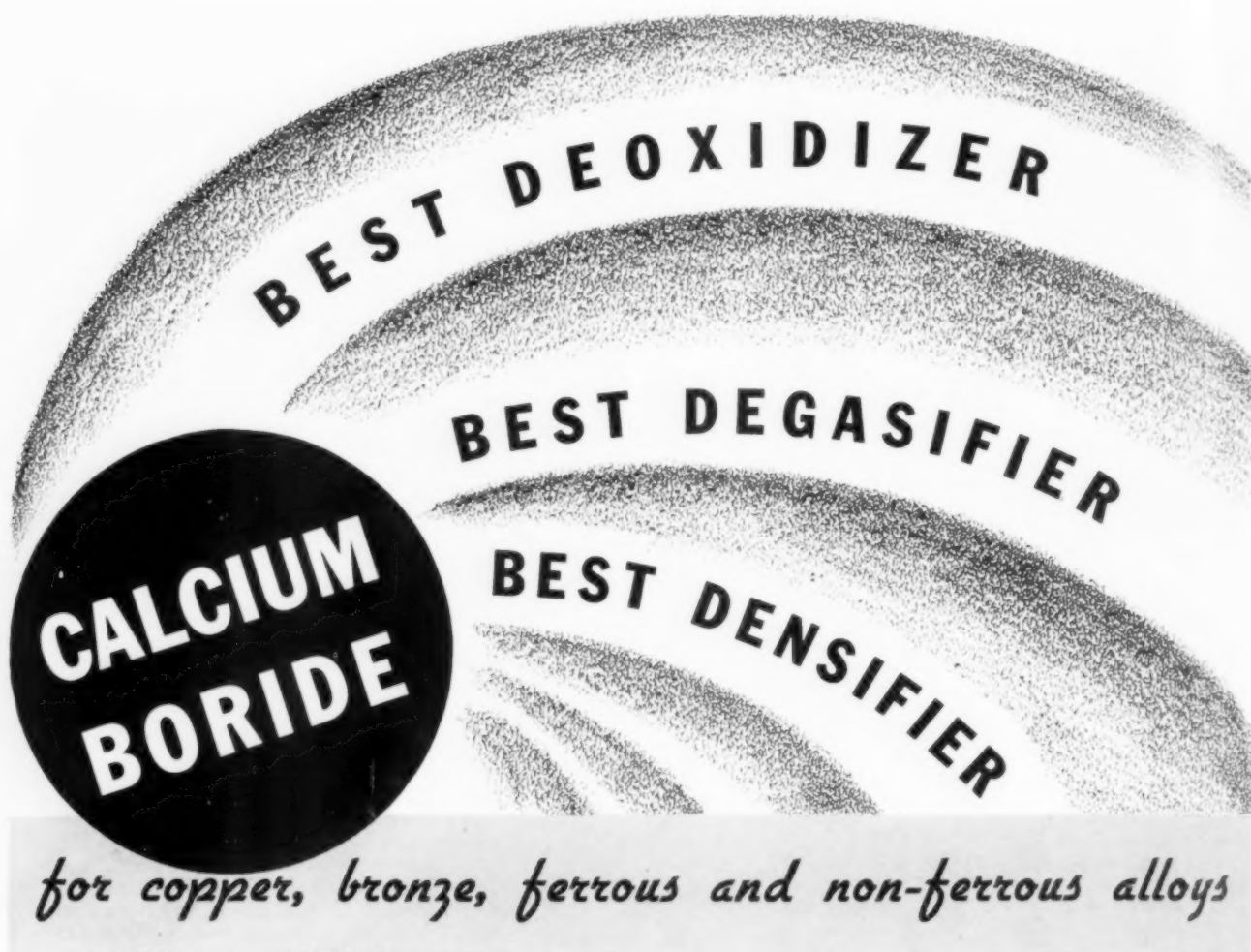
General Office: New York, N. Y.

Offices in Principal Cities

In Canada: Dominion Oxygen Company, Limited, Toronto

**LINDE OXYGEN . . . PREST-O-LITE ACETYLENE . . . UNION CARBIDE
OXWELD, PUROX, PREST-O-WELD APPARATUS . . . OXWELD SUPPLIES**

The words "Linde," "Prest-O-Lite," "Union," "Oxweld," "Purox," "Prest-O-Weld," and "Haynes Stellite" are trade marks of Units of Union Carbide and Carbon Corporation.



★ Calcium Boride contains no critical or strategic elements and is, therefore, not under W. P. B. allocation. It is, consequently, specified today more than ever to replace critical materials formerly used for the same purpose.

Of this, YOU are certain - for sound castings, metals must be completely cleaned of all gases and oxides. This requires a very active agent.

Of this, WE are certain (from users' testimony) - Calcium Boride, an electric furnace product of Electro Refractories and Alloys Corp., is the most thorough de-oxidizing, degasifying and densifying agent. It leaves no residual metal impurities, since it is itself insoluble (disappears in form of slag - after reaction). The fluidity of the metal is not affected. Reactive at normal operating temperatures, Calcium Boride does not, therefore, require excessive super heat.

Furnished in a granular form of 6 mesh or finer.

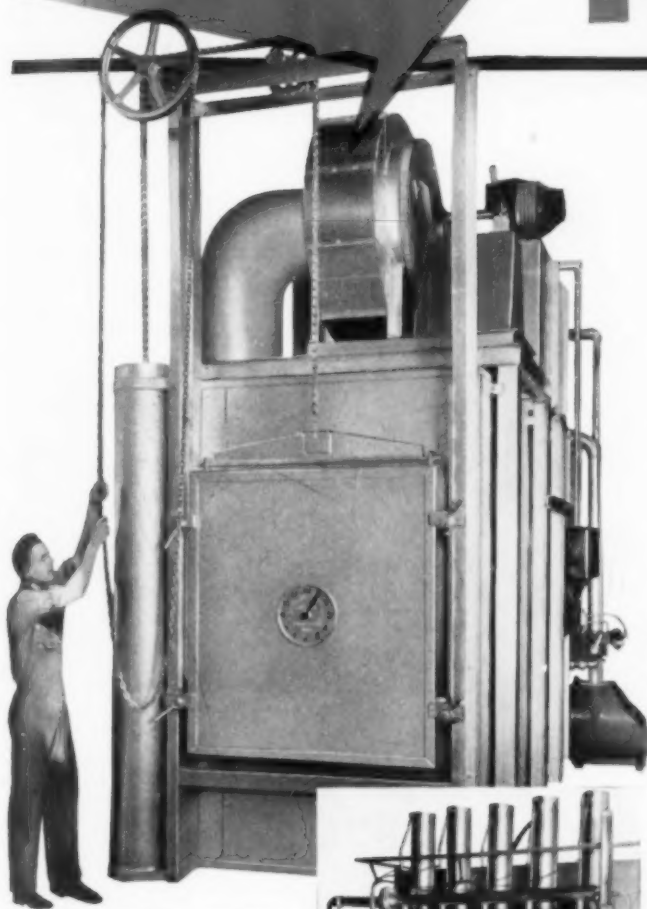
ELECTRO REFRACTORIES AND ALLOYS CORP.

GENERAL OFFICES: ANDREWS BUILDING, BUFFALO, N. Y.

Manufacturers of Crucibles, Alloys, Stoppers, Refractories, Grinding Wheels

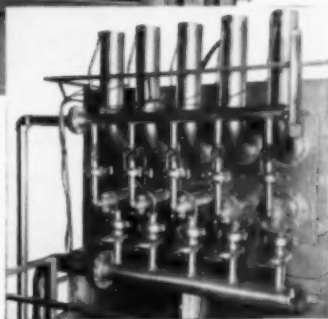
*Let's face the
facts about*

Magnesium HEAT TREATING FURNACES



AIRCRAFT PARTS of magnesium are heat treated in Despatch furnace above. Work chamber is 3' x 4' x 8'. Shelf-loaded; manual or automatic lift door. Also used for solution and aging of Al. castings.

CLEAN HEAT, free of combustion gases, is supplied by this Despatch radiant-tube convection heater. Gas or electric. Very efficient indirect heating for all types of Mg. or Al.



Why you can depend on a Despatch Furnace

Successful magnesium heat-treatment with Despatch furnaces in so many large plants doesn't mean we know everything about magnesium. No one does—yet. But we do know exactly what's needed in furnace design and performance for proper heat-treatment of magnesium. Each Despatch furnace meets all requirements with ease. And in addition each offers many extra features particularly suited to high quality, large-scale production.

These Features Assure Good Results

- 1. Uniformity $\pm 5^\circ \text{F.}$** guaranteed throughout entire heat range. Clean, recirculated convection heat, free of fumes, from radiant tube heater. Indirect gas fired. Handles all Mg. or Al. alloys. (Elec. models also available.)
- 2. Dead Spots Avoided** with controlled airflow from high volume fan. Adjustable ports in heat ducts allow perfect distribution through chamber and load.
- 3. Tight-Sealing** throughout allows use of SO_2 gas. Reduces heat loss and improves working conditions.
- 4. Easy Handling** provided by wide variety of dependable, smooth operating loading systems to fit all requirements. Saves labor.
- 5. Efficient Firing** (Gas or Elec.) is obtained throughout entire heat range to give you the most from fuel used. Quick response to control equipment. Elec. systems use long-life elements.
- 6. Many Sizes:** Prompt delivery available for standard sizes 3' x 3' x 3' up to 8' x 7' x 15'. Pot type elec. models in all sizes to 60" diam. by 60" deep (working dimensions.)

WIRE or PHONE for a Despatch engineer. He will recommend a tested and approved standard Despatch magnesium heat-treating furnace for your plant. Free Bulletin 81 just printed; ask for it.

FURNACES FOR OTHER USES—to 1750° F.
Ask for complete information, photos, etc.



DESPATCH

OVEN COMPANY MINNEAPOLIS MINNESOTA



NITRALLOY

**Not for "extra icing on the cake"
but for winning the war**

Editor E. C. Kreutzberg of "Steel" says this:

"It should be remembered that the present shortage of alloy steels results from the huge Army and Navy demand for them. The Generals and Admirals demand them, not because they want extra icing on their cake, but because tests and experience over many years have enabled them to determine

what materials are best for the waging of war."

Nitralloy and the Nitriding process, producing the hardest steel surface known, are steadily going into the production of vital parts of planes, tanks, ships and other war equipment.

When a just and victorious peace

again makes alloy steels more generally available, Nitralloy and the Nitriding process will contribute to industry their ability to the resistance of wear, fatigue, and abrasion.

For the present, Nitralloy Steels are available under government regulation where needed to help win the war. And that, above all, comes first.

THE NITRALLOY CORPORATION

230 PARK AVENUE • NEW YORK, N. Y.

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ALLEGHENY LUDLUM STEEL CORP...WATERVLIET, N. Y.
BETHLEHEM STEEL CO.....BETHLEHEM, PA.
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REPUBLIC STEEL CORPORATION.....CLEVELAND, O.
THE TIMKEN ROLLER BEARING CO.....CANTON, O.
ROTARY ELECTRIC STEEL CO.....DETROIT, MICH.
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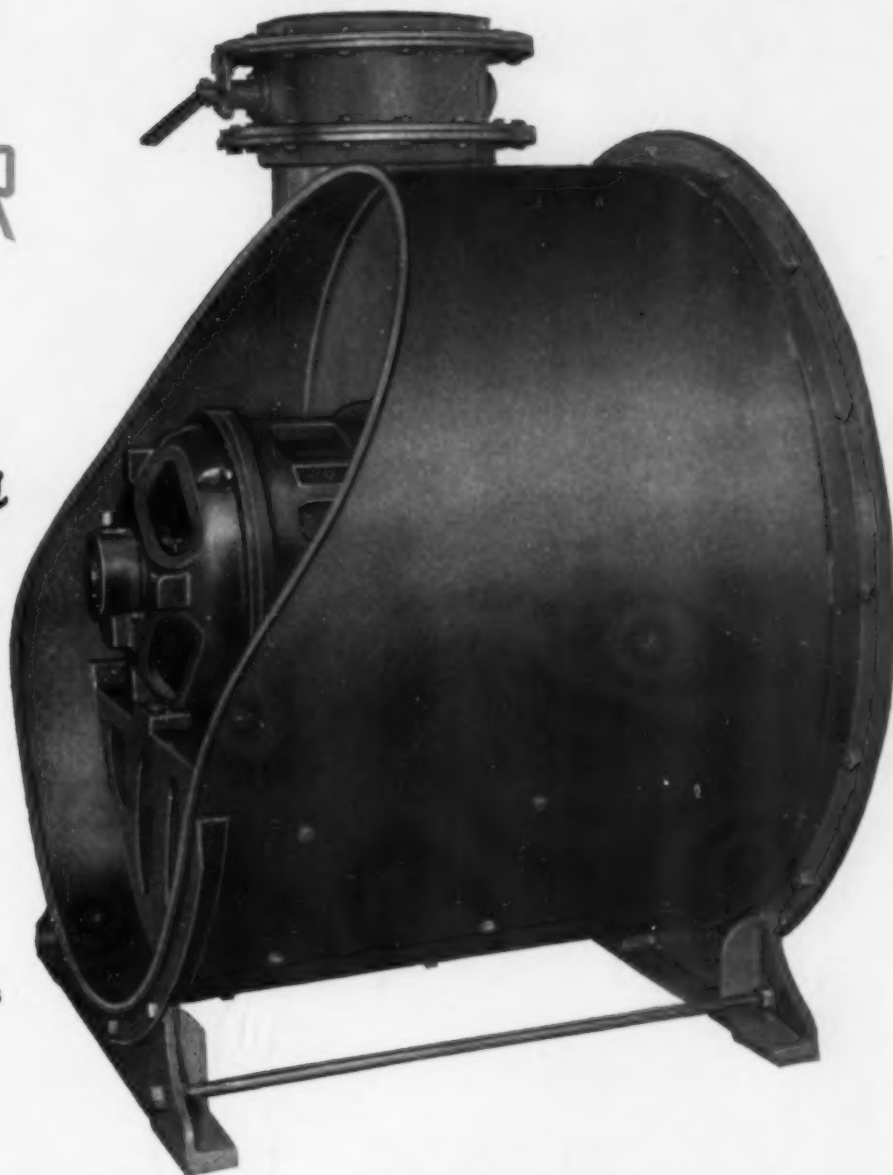
Manufacturers of Nitralloy Steel Castings

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EMPIRE STEEL CASTINGS CO.....READING, PA.
THE MASSILLON STEEL CASTING CO...MASSILLON, O.
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WARMAN STEEL CASTING CO...LOS ANGELES, CAL.

SPENCER
HARTFORD

*Try these
simple tests
on any*

FOR
AIRPLANE TESTING
HEAT TREATING
METAL WORKING
SHIPYARDS
TANKS
GUNS



SPENCER TURBO-COMPRESSOR

1. **Vary the load**—Satisfactory operation without adjusting the blast gate.
2. **Watch the ammeter.** Power is used in proportion to the amount of air used. Efficiency is high at all loads.
3. **Watch the pressure gauge.** It is constant throughout the range from open to closed.
4. **Balance a glass** of water on top of the Turbo. Not even a ripple on the surface of the water!
5. **Listen** for mechanical or air noises. It is unusually quiet.
6. **Examine** a cross-section view. It is as simple as an electric fan, and built like a bridge.
7. **Ask any man** who has used a Spencer for ten or twenty years.
8. **Ask your furnace** or oven manufacturer. He is vitally interested in all-round performance.

THE SPENCER TURBINE COMPANY, HARTFORD, CONN.

TURBO-COMPRESSORS

41-E

December, 1942; Page 1007



Lightning that strikes upward

A voice crackles out of the ether: "*Bandits approaching at 20,000. Scramble!*"

Pilots swarm into planes . . . the shattering thunder of Allison engines jiggles papers on the desks at Flight H.Q. . . . a dozen twin-motored "Lightning" fighters zoom up into combat like missiles slung from a catapult.

These "Lightning" fighters, known in the United States as the Lockheed P-38, clearly demonstrate what American designers, production men and steel-makers can do when they team up on a specialized war job.

Out in Indianapolis they're building the powerful Allison engines that pull the P-38's upstairs at a *vertical mile* a minute, the cannon and machine guns that can rip a bomber apart in midair.

Here in the Bethlehem organization we're working day and night in laboratories and mills to produce steels which will withstand the white-hot combustion temperatures inside a fighter-plane

engine . . . the terrific, crushing pressures of a 600-mile-per-hour pull-out . . . the ever-growing call for more strength and less weight.

In other war products, the story is the same.

Bethlehem bullet-core wire is being turned into millions of rounds of ammunition. Bethlehem high-strength light-weight Mayari R is going into gun carriages, tanks, and planes. Bethlehem's new moly high-speed steels are taking over where the 18-4-1 grades have been ruled out by the tungsten shortage. Bethlehem sheets are going into jeeps, peeps and big prime movers. Bethlehem carbon bars are used as hinge pins, dowel pins and other parts in tanks.

We of Bethlehem fully realize the responsibility of this job. Every day, every month, we are striving to produce more steel, better steel, so more and better weapons can be placed in the hands of our fighting men and our allies. We know that victory won't come easily. But it will come.

BETHLEHEM STEEL COMPANY



MEMORABLE WORDS OF GREAT AMERICANS



Woodrow Wilson

"The wrongs against which we now array ourselves are no common wrongs; they cut to the very roots of human life.

THE WORLD MUST BE MADE SAFE FOR DEMOCRACY"

Woodrow Wilson—28th president of the United States, exponent of many social and economic reforms and creator of the Federal Reserve Banking System, is better known as "World War No. 1 President".

Repudiation at the polls of the League Of Nations was his greatest disappointment.



THERMALLOY *the "EYE" of QUALITY*

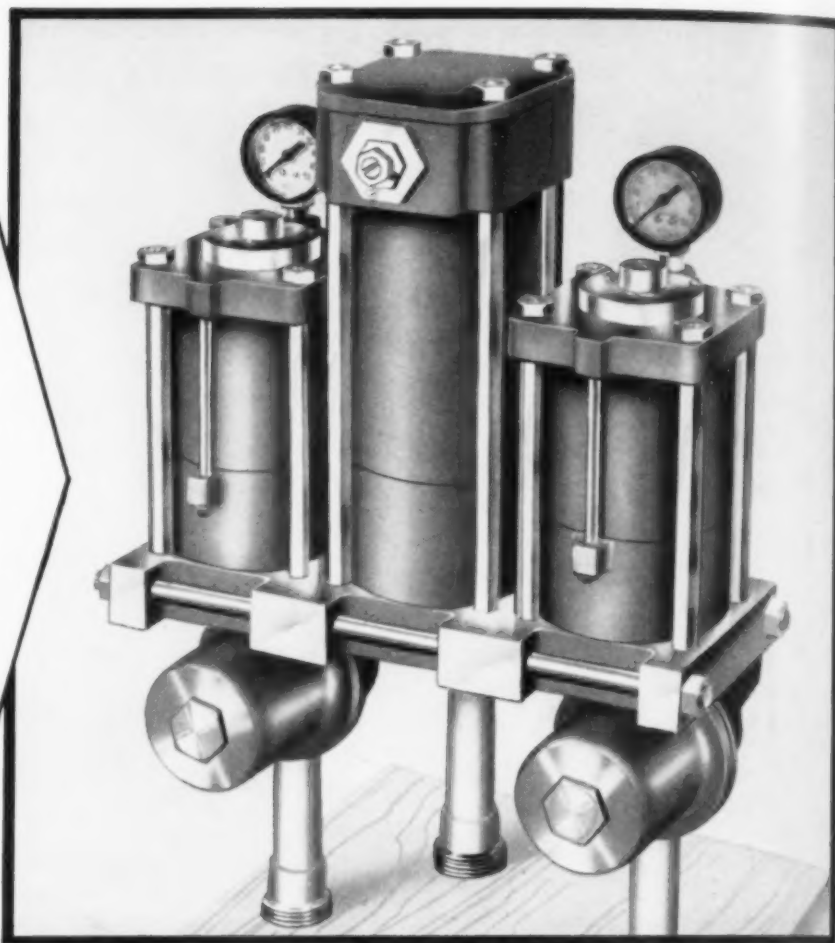
THE ELECTRO ALLOYS COMPANY

CASTINGS FOR HEAT CORROSION
ELYRIA, OHIO



Truly an Instrument of Precision

**Solves problems
of maintaining
the desired tem-
perature in a con-
stant flow of water**



G-E WATER-TEMPERATURE REGULATOR

- *Mixes hot and cold water to within ± 0.5 F of setting.*
- *Automatically maintains this temperature despite wide fluctuations in temperature and pressure of hot and cold supply lines.*
- *Automatically shuts off should either hot or cold supply line fail—thus safeguarding materials in work.*
- *Output rate is selective without change of temperature.*
- *Self-contained—no auxiliary equipment required.*
- *Compact—overall dimensions 10½" by 13" by 4½".*
- *Eliminates the supervision and vigilance usually necessary with devices for regulating the temperature of flowing water.*

A device of this kind suggests many and varied applications. For example, industrial x-ray laboratories are finding it intensely practical for regulating the temperatures of their film-processing solutions, to thus assure a consistently high quality of end results.

If you have a problem involving preciseness of water-temperature control, look to the G-E Regulator for a most practical and satisfactory solution.

Write for Descriptive Catalog No. RR112

**GENERAL  ELECTRIC
X-RAY CORPORATION**

2012 JACKSON BLVD.

CHICAGO, ILL., U. S. A.

Today's Best Buy - U.S. War Bonds

Metal Progress; Page 1010

Announcing

The NEW UPTON HEAT MEASURING CONTROL Heat Treating Temperature Control for Upton Salt Bath Furnaces

- ★ Adds the exact amount of heat for the correct time needed.
- ★ Unbelievably accurate temperature control.
- ★ Corrects operator's setting errors.
- ★ Permits prediction of size change to closer limits.
- ★ Eliminates finish-grinding on many High Speed Steel tools.

The new, tested and proved UPTON Heat Measuring Control temperature controller adds the exact amount of heat for any piece of work, puts the heat into the salt bath for the exact period it is required and then, when the time is up, shuts the heat off and tells the operator to take the work out.

In use for many months on some of the most difficult heat



Milling cutters hardened in this Upton High Heat Furnace require little finish-grinding. With the Upton High Heat Temperature Control, size change is predictable with absolute certainty.

treating operations—where operators with no previous knowledge of heat treating are turning out perfectly treated, high speed steel cutting tools—the Upton Heat Measuring Control even warns the operator if he makes an error in excess of 3°F. in setting the control!

Unlike the conventional "on and off" control with its wide fluctuations, the Upton Heat Measuring Control varies between a "high" and "low" temperature value, rather than an "on" and "off". The current supply never goes "off" except when the operator has made an error. Then it shuts "off" and warns him.

The Upton Heat Measuring Control and a battery of High Temperature Furnaces do not require help experienced in heat treating. All Upton Furnaces, as well as pots are guaranteed. Tell us about your heat treating problem.

Send Now...

for more information about the New Upton Heat Measuring Control.

UPTON ELECTRIC FURNACE DIVISION
Commerce Pattern Foundry & Machine Company

We build the furnace
using the

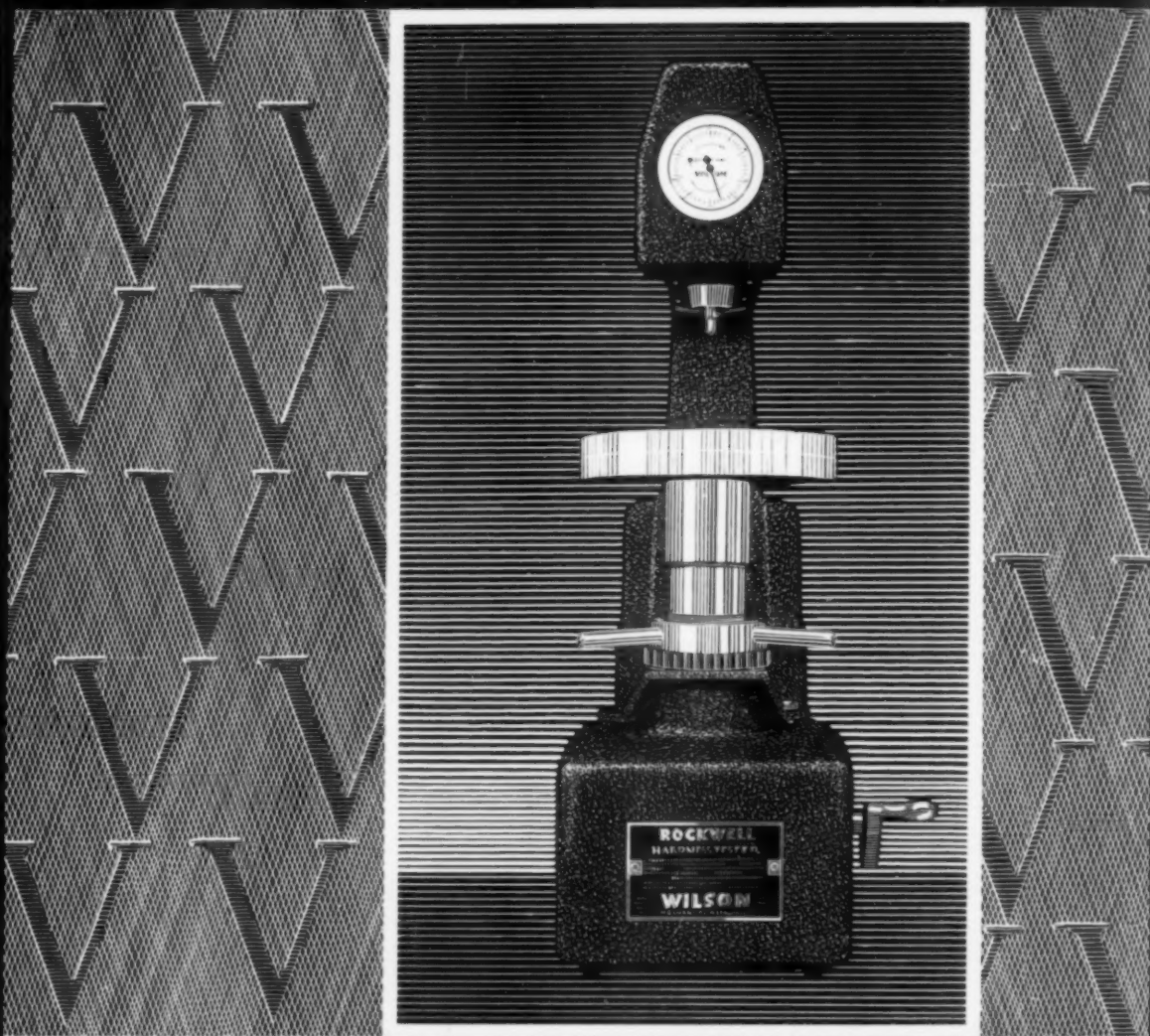
**ELECTROTHERMIC-
PERMEATION**

principle of operation

7435 MELVILLE at GREEN • DETROIT, MICHIGAN

"ROCKWELL"

HARDNESS TESTER



**ITS REPUTATION FOR BOTH INITIAL
AND ENDURING ACCURACY HAS
BEEN GROWING CONSTANTLY FOR
A FIFTH OF A CENTURY**

WILSON

CONCORD AVE · NEW YORK MECHANICAL INSTRUMENT CO., INC.

THE GRIM VISAGE OF
WAR IS REFLECTED
FROM MANY SURFACES

Those receiving new "ROCKWELL" Hardness Testers are asked to realize that the surface finish of our castings is restricted by a limitation order of our government.

Precision, durability and operational quality, however, are better than ever.

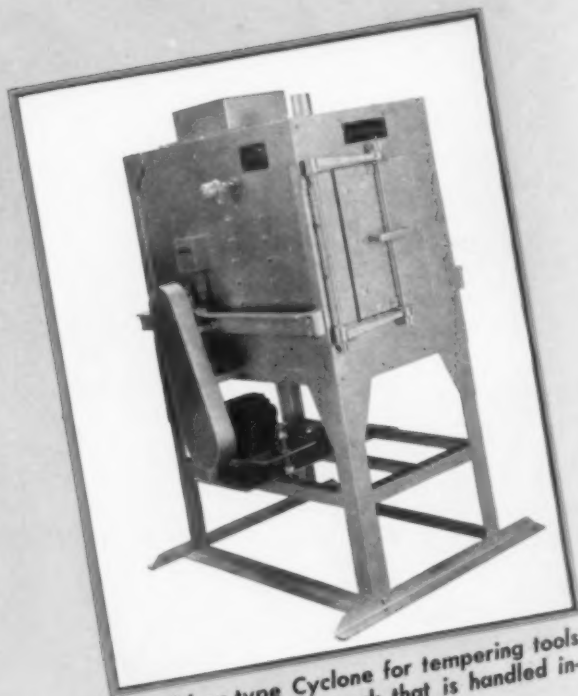
WILSON MECHANICAL INSTRUMENT CO., Inc.
NEW YORK

December, 1942; Page 1013

THIS IS ABOUT THE **SIZE** OF IT



Large box type Cyclone for aluminum and magnesium heat treatment.



Small box type Cyclone for tempering tools and dies or other work that is handled individually.



Large vertical type Cyclone for production tempering. Its accuracy of heating and control also makes it ideal for aluminum and magnesium heat treatment.



Small vertical type Cyclone Furnace for heat treating small parts. Note basket in lower right hand corner.

The accuracy and uniformity of heating is consistent throughout the entire range of sizes

SPECIFY STANDARD SIZES when ordering heat treating equipment. Valuable time is saved because drawings are available and all engineering has been completed. Man hours are saved by the elimination of special work in both engineering and the shop. And heat treating furnaces are sped to their destination to do their chosen work.

The dimensions listed below represent standard sizes of both vertical type and box type Lindberg Cyclone Furnaces. Each of these furnaces has been engineered and built and installed in the field.

The sizes embrace a range wide enough to handle practically any heat treating job for temperatures up to 1250°F.

LINDBERG VERTICAL TYPE CYCLONE FUEL FIRED

Utilizes the famous Lindberg 100% forced convection heating principle, available in both fuel fired and electrically heated units. Work is handled in baskets or on fixtures for accurate,

uniform, low-cost tempering and precision heat treatment of aluminum and magnesium castings and forgings. Temperatures from 250°F. to 1250°F.

Dia.	Depth	Dia.	Depth	Dia.	Depth	Dia.	Depth	Dia.	Depth	Dia.	Depth	Dia.	Depth	Dia.	Depth
12"	16"	16"	36"	22"	72"	25"	160"	28"	72"	38"	28"	43"	48"	60"	72"
12"	100"	22"	26"	25"	20"	28"	28"	33"	28"	38"	30"	43"	54"	72"	24"
16"	20"	22"	30"	25"	30"	28"	36"	33"	36"	38"	36"	48"	28"	74"	72"
16"	22"	22"	36"	25"	36"	28"	42"	33"	40"	38"	48"	48"	38"	74"	86"
16"	26"	22"	38"	25"	40"	28"	48"	33"	48"	38"	60"	48"	48"	100"	44"
16"	28"	22"	48"	25"	48"	28"	50"	33"	60"	38"	72"	48"	60"	—	—
16"	32"	22"	60"	25"	60"	28"	60"	33"	72"	38"	84"	48"	78"	—	—

ELECTRICALLY HEATED

Dia.	Depth	Dia.	Depth	Dia.	Depth	Dia.	Depth	Dia.	Depth	Dia.	Depth	Dia.	Depth	Dia.	Depth
8"	10"	16"	20"	22"	36"	25"	30"	28"	28"	33"	36"	38"	120"	48"	96"
8"	12"	16"	24"	22"	48"	25"	36"	28"	36"	33"	120"	43"	42"	60"	60"
10"	14"	16"	26"	22"	60"	25"	40"	28"	48"	38"	36"	43"	48"	60"	72"
10"	20"	16"	28"	22"	72"	25"	42"	28"	54"	38"	48"	48"	36"	60"	84"
12"	16"	16"	32"	22"	80"	25"	48"	28"	60"	38"	60"	48"	60"	60"	93"
12"	18"	16"	48"	22"	100"	25"	60"	28"	72"	38"	72"	48"	72"	—	—
12"	20"	22"	26"	25"	20"	25"	66"	28"	84"	38"	84"	48"	84"	—	—

LINDBERG BOX TYPE CYCLONE FUEL FIRED

Is also heated by 100% forced convection and is also available in both fuel fired and electrically heated units. Recommended for tempering tools or dies or other work that is handled individually. Its heating accuracy and control make the box

type Cyclone ideal for heat treating aluminum and magnesium castings, stampings and forgings. Temperatures from 250°F. to 1250°F.

Width	Depth	Height	Width	Depth	Height	Width	Depth	Height	Width	Depth	Height
12"	16"	18"	24"	48"	18"	36"	36"	24"	48"	12"	60"
15"	24"	18"	24"	24"	20"	36"	54"	30"	54"	72"	36"
17"	24"	18"	30"	48"	40"	36"	72"	30"	60"	96"	42"
18"	36"	18"	30"	48"	48"	36"	72"	36"	72"	12"	42"
24"	24"	18"	30"	72"	24"	36"	92"	24"	—	—	—
24"	36"	18"	36"	22"	24"	42"	72"	36"	—	—	—

ELECTRICALLY HEATED

Width	Depth	Height	Width	Depth	Height	Width	Depth	Height	Width	Depth	Height
12"	16"	18"	24"	48"	18"	42"	14"	36"	52"	84"	20"
12"	12"	10"	28"	28"	36"	48"	60"	30"	60"	60"	42"
15"	24"	18"	30"	30"	24"	48"	66"	48"	60"	10"	42"
15"	24"	24"	33"	34"	30"	48"	72"	30"	60"	10"	60"
15"	30"	18"	36"	36"	24"	48"	72"	36"	60"	16"	60"
15"	48"	18"	36"	48"	24"	48"	72"	48"	66"	15"	66"
18"	36"	18"	36"	54"	30"	48"	72"	60"	66"	16"	76"
20"	24"	18"	36"	72"	24"	48"	96"	36"	66"	25"	76"
20"	30"	18"	40"	96"	24"	48"	10"	72"	72"	96"	84"
20"	36"	18"	42"	16"	36"	48"	12"	72"	72"	12"	42"
24"	24"	18"	42"	16"	66"	48"	16"	72"	84"	96"	72"
24"	36"	18"	42"	72"	36"	48"	18"	72"	—	—	—
24"	36"	30"	42"	84"	42"	48"	22"	66"	—	—	—

LINDBERG ENGINEERING COMPANY
2448 WEST HUBBARD STREET • CHICAGO

HYDRIZING FOR SCALE-FREE AND DECARB-FREE HARDENING

LINDBERG FURNACES

SUPER-CYCLONE FOR HARDENING, NORMALIZING, ANNEALING, TEMPERING, NITRIDING



to help YOU do

in the production of STAINLESS PARTS

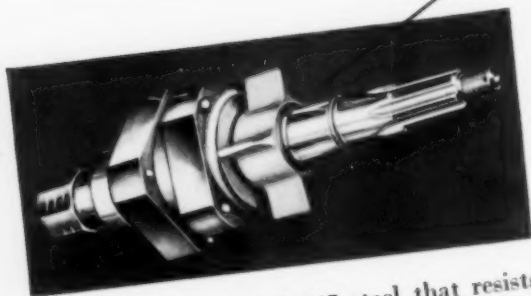
► **HINTS** on how to get the most from every pound of Stainless Steel you use.

► **TIPS** on how to increase production, how to do the job better.

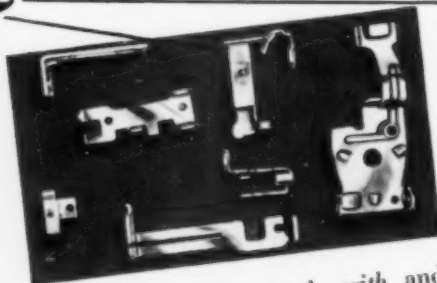
You and your men no doubt know many short-cuts as a result of your experience in fabricating Stainless Steel. We like to help you add to that knowledge by giving you the benefit of our experience in solving Stainless problems.

So we are passing along some of the suggestions collected from Carpenter metallurgists, research men and service representatives. Most of these men have devoted a good part of their lives to solving Stainless problems. Today through their efforts, better and faster fabricating methods are available to war production plants.

In many of these plants, Carpenter men are being asked to solve special corrosion and heat resistance problems... and then work out faster fabricating methods. Because time is short, they can not be everywhere at once. But much of their experience can be made available to you through these pages, and by correspondence with the mill... Write us about your specific Stainless problems.



EASY-TO-MACHINE steel that resists corrosion is needed for making magneto shafts like this... so Carpenter Free-Machining Stainless is used to eliminate many production headaches.



SEVERE BENDING both with and against the grain is no problem with soft and ductile Carpenter Stainless Strip. Then too, these switch parts must be made to close tolerances—with fewer rejects—an easier job with this Stainless Strip.



TERRIFIC HEAT and corrosion "up" on airplane exhaust manifold so Stainless is used to make trip "home" possible. (And here that the high strength ratio of Stainless improves performance.)

do a trouble-shooting job



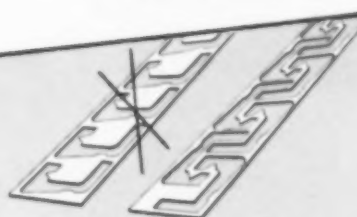
Adjust Press Speeds For MORE Output!

Perhaps your press speeds are OK. Maybe faster speeds should be used. A quick check-up may even show that a reduction of 10 to 15% would increase output and conserve metals. Often, slower press speeds will overcome die galling that can spoil parts and interrupt production.



Saved: 30,000 Pounds of Stainless!

From 45,000 lbs. of Stainless Sheet to only 15,000 lbs. of narrow Stainless Strip — for making the same number of parts! Saved: 30,000 lbs. of vital metal, and the time required to slit and handle sheet. Check the use of narrow Strip on your jobs where Sheet is used.



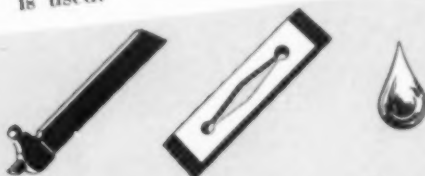
Re-Check Layouts --- NOW!

Keep your skeleton scrap losses to an absolute minimum. Spend a few hours now to re-check layouts on jobs that are stamped from Strip. The results will be well worthwhile... in terms of metal conserved and time saved.



"Tell All" to Your Supplier...

Tell your supplier about your punch press problems, your machining difficulties and high percentage of rejects. He made the material you use, and can probably offer plenty of good, solid help and useful information.



How About... Tools? ... Dies? ... Lubricants?

Frequently, an analysis of your tool, die and lubricant set-up will point the way to getting rid of tough production "bugs". A complete review of procedure can do a lot to help you boost output and conserve much-needed metals.



"Much scrap. So happy."

Check Your Rejects...

Material that is not uniform throughout can cause many a headache such as wrinkling in the die. Tearing and galling can also result from using off-size material. But whenever rejects are high, it pays you to check all along the line.



AND remember that your Carpenter representative and our Metallurgical Department can provide on-the-spot help... to enable you to beat your really tough problems.

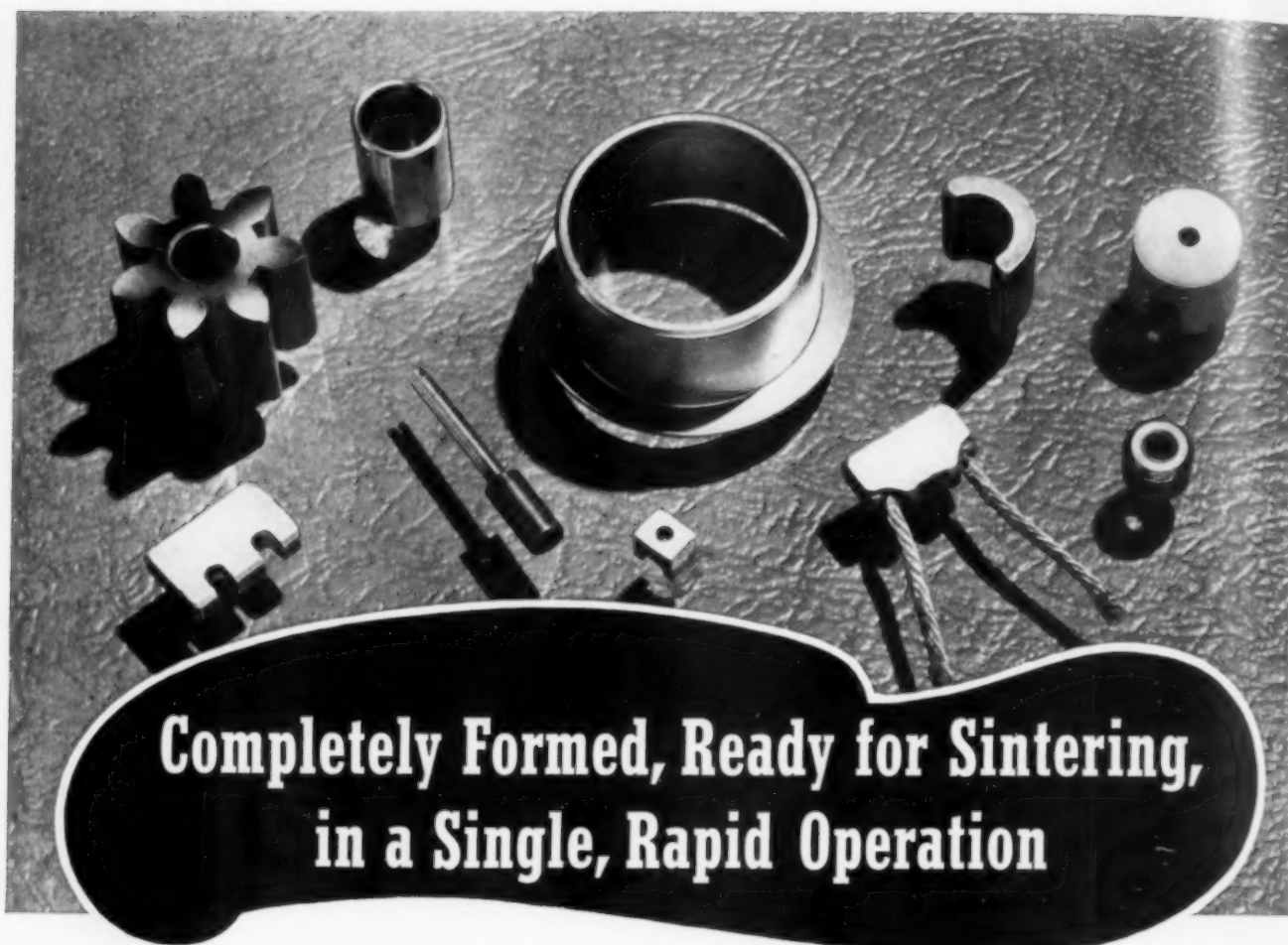
The Carpenter Stainless Slide Chart is a useful "assistant" to have at your elbow. It provides data on the welding, heat resisting and machining properties, etc. of each Stainless Steel. A note on your company letterhead will bring you a Carpenter Slide Chart—free to Stainless Steel users in the U.S.A.

THE CARPENTER STEEL COMPANY, 133 Bern Street
Reading, Pennsylvania



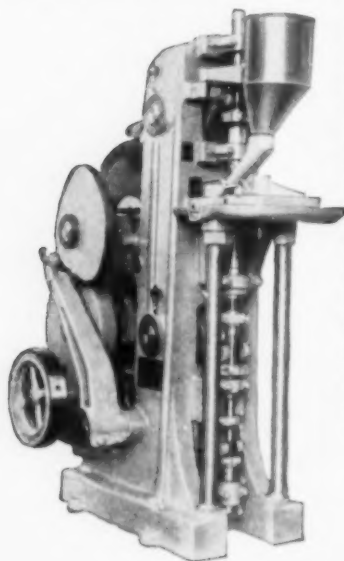
Carpenter STAINLESS STEELS

BRANCHES AT Chicago, Cleveland, Detroit, Hartford, St. Louis, Indianapolis, New York, Philadelphia



Completely Formed, Ready for Sintering, in a Single, Rapid Operation

Many parts for war production are made more efficiently *and faster*, from powdered metals . . . small ordnance components, porous bearings, iron gears, motor and generator brushes, hard carbide tool bits, contact points, others.



Stokes Automatic Presses are widely applicable, produce intricate as well as simple parts. Rates are up to hundreds per minute, varying with the size, material and character of the piece. On small pieces, such as chemical catalysts, production of thousands per minute is obtained.

In manufacture by powder metallurgy density

is readily controlled, to obtain high porosity, as required in porous bearings, or the extreme density necessary in hard carbide tools. Parts are formed in a single operation, ready for sintering. Tolerances are maintained within close limits and parts are remarkably uniform in physical characteristics.

Stokes Presses are the result of 25 years of research and development work in powder metallurgy. They are available in standard and "special" models, with up to 8" die-fill and to make parts up to 4" dia.

Write for new 48-page, illustrated catalog, with machine specifications, engineering data, information on selection of equipment, etc. Our engineering and laboratory facilities are available and consultation on specific problems is invited.



F. J. STOKES MACHINE COMPANY

6006 Tabor Road Olney P. O. Philadelphia, Pa.

Representatives in New York, Chicago, Cincinnati, St. Louis, Cleveland, Detroit
Pacific Coast Representative: L. H. Butcher Company, Inc.

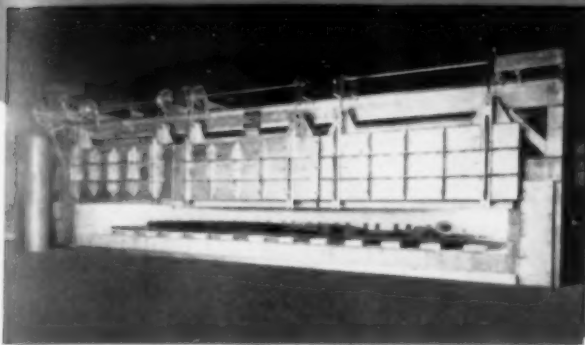
F. J. Stokes

**AUTOMATIC
TABLETTING EQUIPMENT**



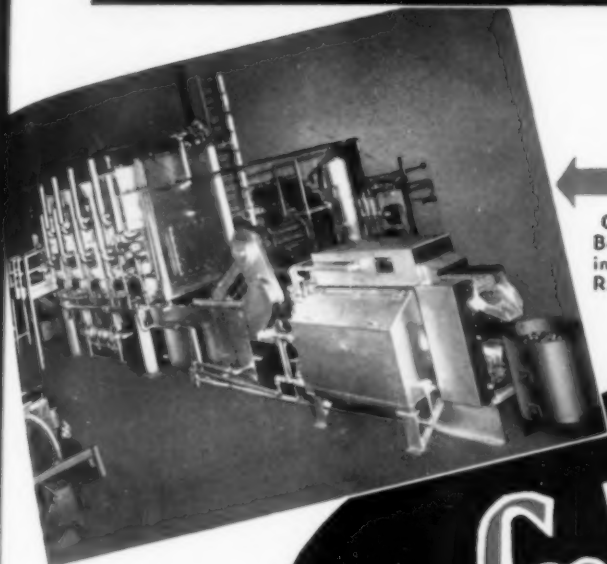
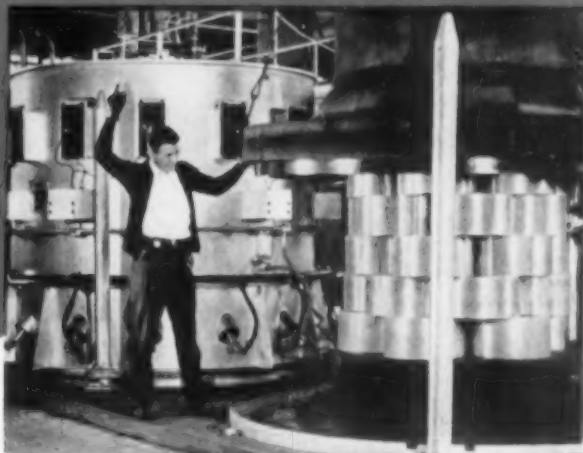
Lee Wilson offers

Specialized Engineering Services for all types of INDUSTRIAL FURNACES



Side Door Heat Treating
Furnace for Long Bars

Brass and Copper Coil Bright Annealing in Bell
Type Furnace—Radiant Tube Heated



Continuous
Bolt Hardening
Furnace—
Radiant Tube
Heated

Roller
Hearth
Furnace for
Heat Treating
Plates



Lee Wilson

ENGINEERING Co. Inc.

20005 West Lake Road CLEVELAND, OHIO
ACADEMY - 4670

Small Car Type
Furnace



Pusher Type
Normalizing Furnace

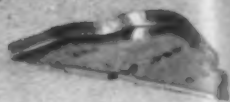
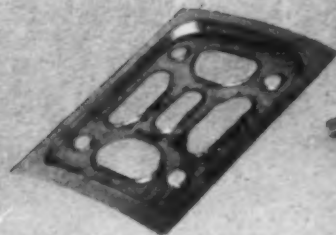


BUY
WAR SAVINGS
BONDS



The Wilson Annealing
Unit is covered by
Patents Nos. 1,935,402
2,088,477, 2,078,396, 2,
361,812, 2,093,843, and
other patents pending

Cecostampings



Radio panel and gaskets made of aluminum alloy.



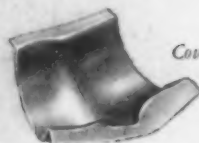
Airplane door of aluminum alloy made on a 48" x 36" Cecostamp.



Half an airplane window and door frame made on a 66" x 36" Cecostamp.



Airplane nose or spinner of stainless steel made on a 66" x 48" Cecostamp.



Cover

Unlike most other machinery being used in the war effort, the Cecostamp is something new in production machinery. An original design by Chambersburg Engineering Company, the Cecostamp is a high production impact type stamping machine for forming high strength sheet metal parts such as stainless steel and many aluminum alloys. By using a Cecostamp, it is possible to form difficult metals with greater true-to-die accuracy and fewer operations. The operator has control at all times of the metal flow of the stamping and is able, therefore, to produce desired shapes without drawing or a reduction in sectional areas. Controlled stamping overcomes the resiliency of hard-to-form metals while giving them a permanent set at a greater rate of production. A few examples of Cecostampings are shown.

For complete details of Cecostamping and more examples write for a copy of "Cecostampings."

**CHAMBERSBURG ENGINEERING CO.
CHAMBERSBURG PENNA.**

CECOSTAMP

The modern drop stamp for difficult forming of high strength steel and aluminum alloy sheet metal parts.



**CHAMBERSBURG
CECOSTAMP
HAMMERS PRESSES**

Deepfreeze Santocel Cascade Industrial Chilling Unit. Capable of maintaining temperatures as low as -120° Fahrenheit.

**Removes 1000 B.T.U.'s
Per Hour at -120° F.
Effects Savings Up To \$2825
Per Year Over Dry Ice**

In addition to eliminating the inconvenience of handling dry ice, the Deepfreeze Cascade Chilling Unit produces and maintains a temperature substantially 29 degrees colder. Laboratory tests prove that the cost for removing 1000 B.T.U.'s per 24-hour day over a period of one year with dry ice is \$3000.00, as compared to the \$175.00 electric current consumption of the Deepfreeze over the same period of time.

THE DEEPFREEZE STANDARD CASCADE INDUSTRIAL CHILLING UNIT has a chilling chamber 24" in diameter by 30" deep. It is equipped with two motors and two compressors of the silent-valve-head, water-cooled, piston type. It has a heat absorbing capacity equivalent to 196 lbs. of dry ice per 24-hour day under similar operating conditions.

The same standard unit can be furnished 60" deep or deeper.



*Special
Units
Designed
for
Specific
Needs*

In addition to the standard Deepfreeze units, special units can be designed to suit specific applications. Extra deep chilling compartments have been furnished for shrinking airplane retractable landing gear parts in assembly. Many other designs are being furnished, each to suit a specific problem.

Other special designs have been furnished for desiccating blood plasma, shell freezing blood plasma, and for testing aircraft instruments at all flying levels and temperatures.

FREE ENGINEERING ASSISTANCE

Deepfreeze engineers are available to assist you in obtaining the advantages of sub-zero metal conditioning. Send us an outline of your problems, together with parts or prints for a preliminary calculation and test—no obligation.



FREE DATA and proof of the outstanding success of the Deepfreeze method for chilling metals is included in this booklet. Write for your copy today.



How to Use Sub-zero Temperatures in Metal Working

*... Deepfreeze Metal Chilling
Increases Production Efficiency
in Fabricating Tool Steel, Bronze,
Brass, Aluminum and Magnesium Parts . . .*

MANY long-recognized metal working problems are finding solution in industry's newest helper—*Metal Chilling*. Among its unlimited uses are the following:

Shrinking of Metal at -100° F. to -120° F. has made it possible to assemble bearings and similar parts requiring a press-fit by merely slipping them into position . . . eliminates spoilage caused by "pounding" bearings into place . . . saves time caused by delay in replacing bearings . . . saves cost of expensive equipment.



Another application is in chilling aluminum alloy rivets 17S-T and 24S-T to retard aging. Rivets can be kept soft enough for driving for a period of over two weeks.

Testing of Metals at -100° F. to -120° F. has made it possible to study the reactions of aircraft instruments to stratosphere flying. Aircraft engine lubricants can also be pretested for sub-zero flying. Tests are usually conducted over a 6 or 8-hour freezing period.



Treating of Metal at -100° F. to -120° F. will produce combinations of hardness, strength and ductility not obtainable by ordinary hardening or tempering. "For treatment of high-speed steel, temperatures colder than -150° F. are ineffective. Temperatures warmer than -100° F. are also ineffective."



The Deepfreeze Cascade Unit is capable of maintaining -120° F., making it ideal for the proper treatment of high-speed steel.

Deepfreeze

DIVISION

MOTOR PRODUCTS CORPORATION

2325 DAVIS STREET, NORTH CHICAGO, ILLINOIS

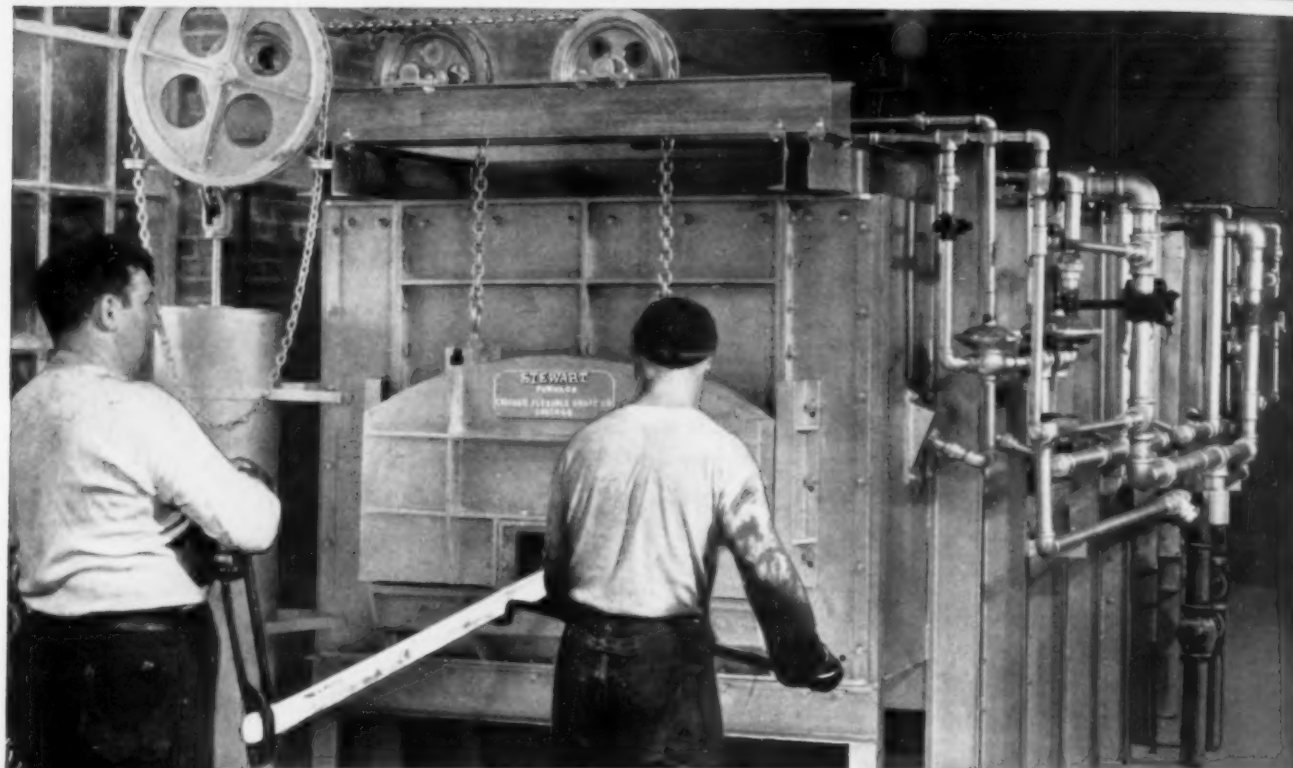
HEATING *and* DRAWING COIL SPRINGS *with*

No. 40
OF A
SERIES
of Typical
Installations

STEWART

THE BEST INDUSTRIAL FURNACES MADE

THE BEST INDUSTRIAL FURNACES MADE



The Stewart Rod Heating Furnace illustrated above is used by the William D. Gibson Company, Chicago, to heat steel rods from ½" dia. to 2¼" dia., to a range from 1700° to 2200° F., depending upon the type of steel. It is equipped with a two-zone temperature control, each operating independently of the other. The combustion chamber is fired by tangential burners equally staggered for proper heat distribution. The end burners are slightly larger than the others and are hand controlled to compensate for heat loss at the doors. The end burners are so arranged that when the furnace goes on high, the burners go on high, but when the furnace goes on low, the end burners maintain the original hand set position. This type of control assures equal heating of the entire bar. This installation is typical of the industrial furnaces Stewart engineers are building every day to meet the specified requirements of manufacturers all over the continent. Stewart builds, in addition, a full line of standard type furnaces.



NEW REVISED STEWART WALL CHART

Write for Your Free Copy

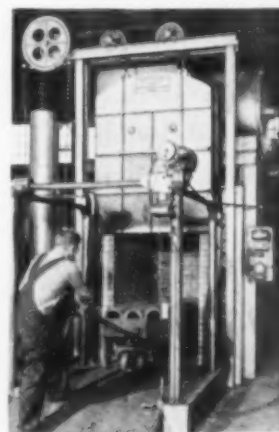
Has the latest NE Steels, 1942 S. A. E. Steels, Heat Treatments, supplementary A. I. S. I. Steels, and other data. Convenient 21" by 23" size for framing. One of the most popular aids for heat-treating men in the industry. We will be glad to send you a copy with our compliments upon request.

A letter, wire or 'phone call will promptly bring you information and details on STEWART Furnaces, either units for which plans are now ready or units especially designed to meet your needs. Or, if you prefer, a STEWART engineer will be glad to call and discuss your heat-treating problems with you.

STEWART INDUSTRIAL FURNACE DIV. of CHICAGO FLEXIBLE SHAFT CO.

Main Office: 5600 W. Roosevelt Road, Chicago, Illinois

Canada Factory: (FLEXIBLE SHAFT CO., LTD.) 121 Weston Rd., So., Toronto



After coiling and quenching, the spring is drawn in the Stewart Hot Air Recirculating Tempering Furnace shown above.

Vital War Work Speeded by Repair Weld



Bronze Welding Repairs 2½-ton Gear

Delay Avoided on 75 Mm Shell Production

Bronze Welding in Action on the Home Front —

Big Press Salvaged by Bronze Welding

Repair Weld Saves Month on A-1-a War Order

Under the strain of all-out production, some equipment failures are bound to occur. Should it be a key machine or important piece of equipment in a vital industry, an extended delay may be serious. Replacement may take weeks or months—or even longer. • That's where Bronze repair welding has come to the rescue time and time again. Bronze welding has put fractured and broken machines back on the job in days instead of months . . . has reclaimed worn equipment by building up wear resisting surfaces. Costly or irreplaceable production equipment has been salvaged at a fraction of its original cost, and schedules have been maintained with a minimum of interruption. • Tobin Bronze*, developed by The American Brass Company, was one of the first all-around oxy-acetylene welding rods. Today, this low-melting-point rod is indispensable for repairing and reclaiming worn and broken equipment made of cast iron, malleable iron, steel or copper and its alloys. In addition to Tobin Bronze, other modified alloys such as Anaconda "997" (Low Fuming) are available for practically every Bronze welding requirement. • Investigate ALL the possibilities of this fast, dependable, low-cost method of repair that is saving days, delays and countless dollars in every branch of industry.



THE AMERICAN BRASS COMPANY

General Offices: Waterbury, Connecticut

*Reg. U. S. Pat. Off.

These illustrations tell a convincing story . . .

If it's cast iron, steel, malleable iron or copper alloys—
If it's broken or damaged or hard to replace—

DON'T SCRAP IT-

**Bronze welding will
put it back in action!**

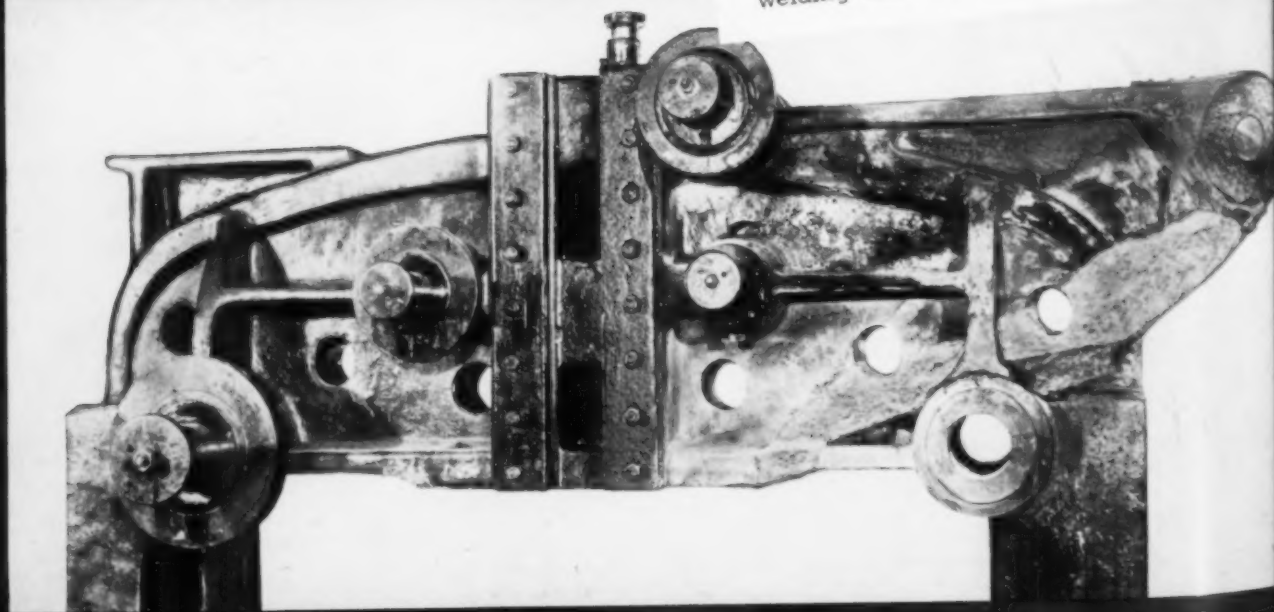


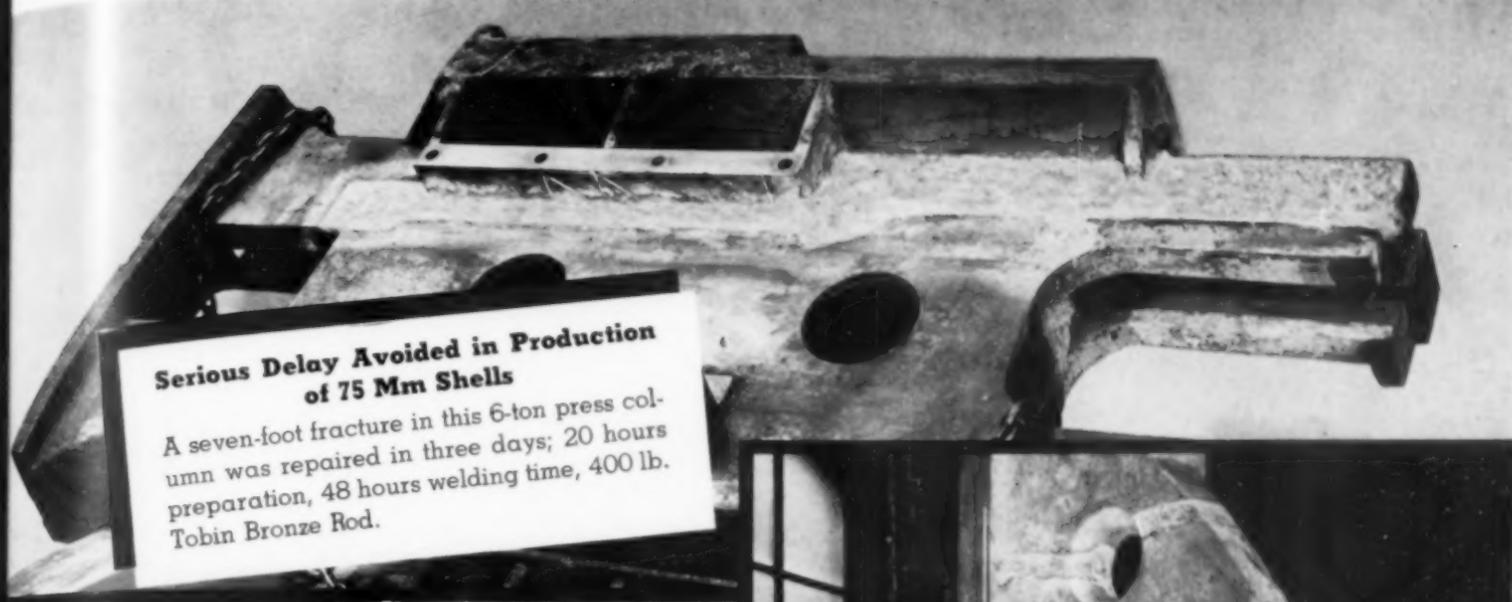
**2½-Ton Gear—Broken in
Several Places—What to Do?**

A new one meant patterns, castings, weeks of machining—months of delay. Tobin Bronze repair welding had the gear back in operation—welded and machined—in less than a week.

**15-Ton Press Crown Back
in Action in a Week**

Again Tobin Bronze to the rescue—1150 pounds of it—to restore this fractured 15-ton casting. Bearings were in alignment after welding and no machining was necessary.





Serious Delay Avoided in Production of 75 Mm Shells

A seven-foot fracture in this 6-ton press column was repaired in three days; 20 hours preparation, 48 hours welding time, 400 lb. Tobin Bronze Rod.



119 Man-Hours and "997" Rod Restores Big Press to Service

"Months to replace" was the bad news when this press housing gave way on all-out war work. But 400 lb. of Anaconda "997" (Low Fuming) put it back on the production line.



"997" Repair Weld Saves Month's Loss on A-1-a War Order

Requiring only 75 lb. of Anaconda "997" (Low Fuming) Rod, and 39 man-hours for chipping and welding, this fractured 2-ton section of a 100" boring mill was speedily returned to service.

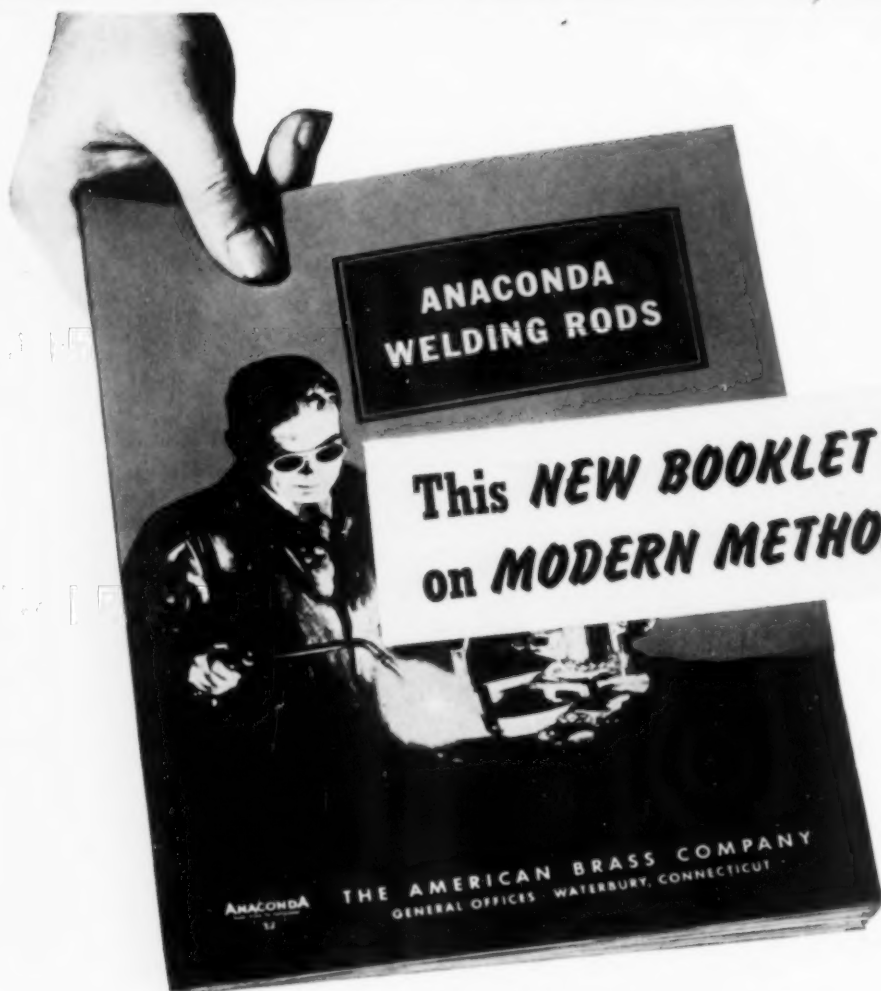


Vital War Work Speeded by Tobin Bronze Repair Weld

14-ton ram, idle several years, suddenly needed for war production. Inspection showed bad fracture. Six days later, repair welded, the ram was ready for work.

ANACONDA
from mine to consumer

A new edition of
"Anaconda Welding Rods"
is yours for the asking.
Use the convenient coupon
on the next page.



**This NEW BOOKLET will keep you posted
on MODERN METHODS of Bronze Welding**

So universal has the use of Bronze welding become in recent years that Anaconda Welding Rods have been adopted as standard materials for oxy-acetylene repair and construction work in many fields. Electric welding of copper alloys has also made tremendous strides. To assist you in keeping up-to-date on construction and repair welding with copper alloy welding rods, this latest edition of Anaconda Publication B-13 is now available. It outlines practices to follow and the type of rod to use for oxy-acetylene welding and various methods of electric welding. It lists 14 principal Anaconda Welding Rods together with their compositions, melting points and suggested uses. The melting points and temperature colors of commonly used metals and alloys are graphically illustrated. To get your copy simply fill out and mail the form below.



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"Anaconda Welding Rods"

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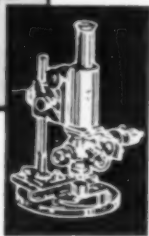
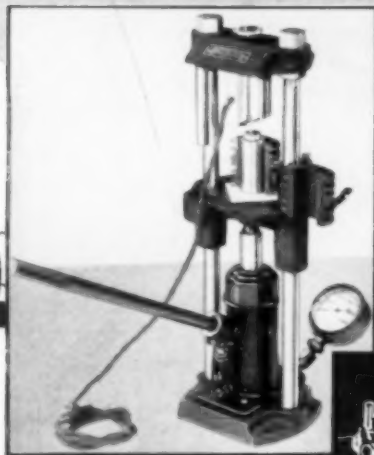
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Christmas greetings to our customers and friends who have helped to make 1942 one of the best business years in our history. We fervently hope that we shall continue to enjoy these friendly relations during the coming year, and that 1943 will see the fulfillment of "Peace on Earth; Good Will Toward Men."



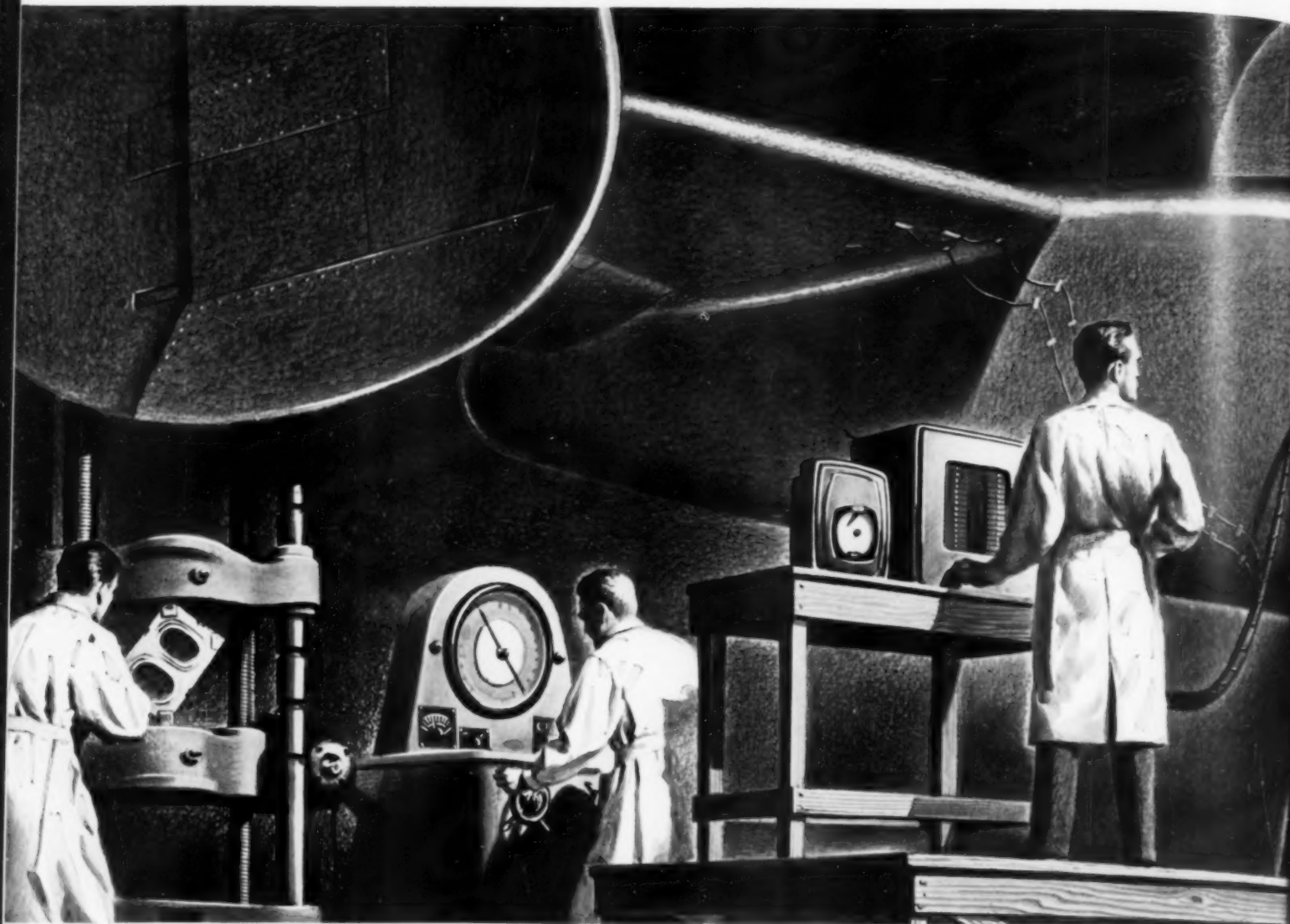
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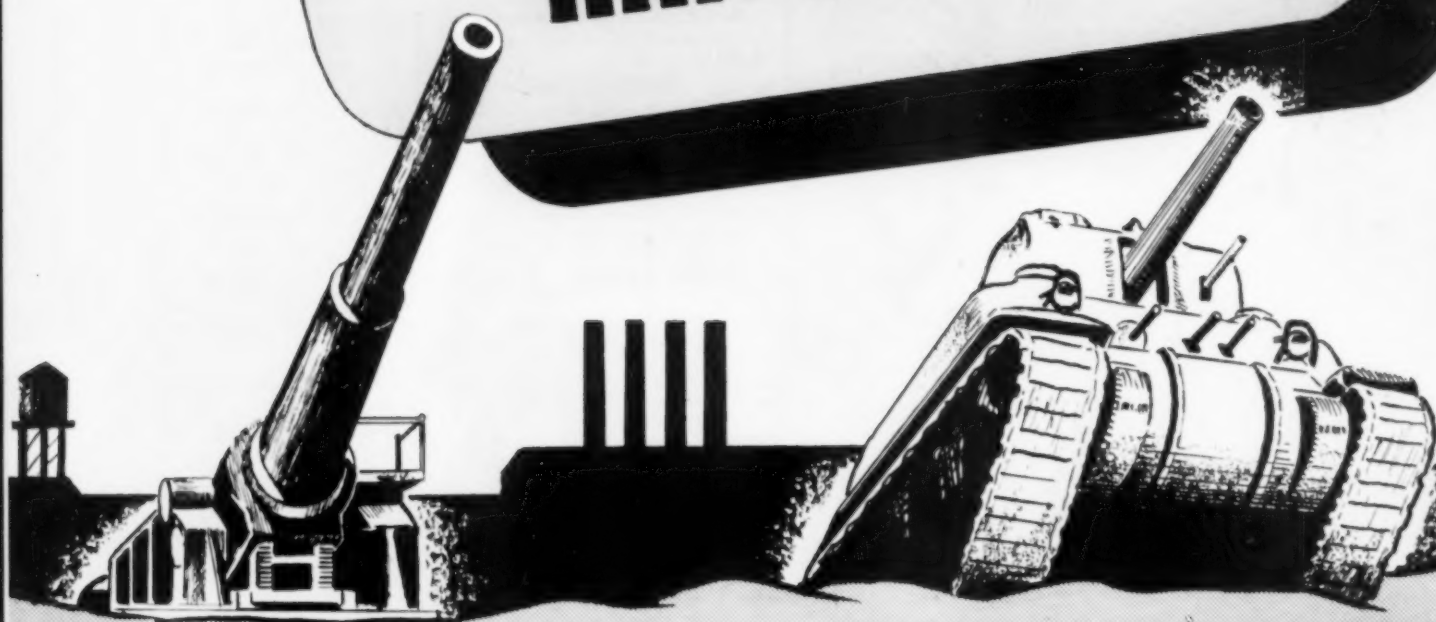
Answers Navy Spec. No. 51-F-4A, Air Corps Spec. No. 11316-A, Federal Ordnance Dept. Spec. No. AXS-500

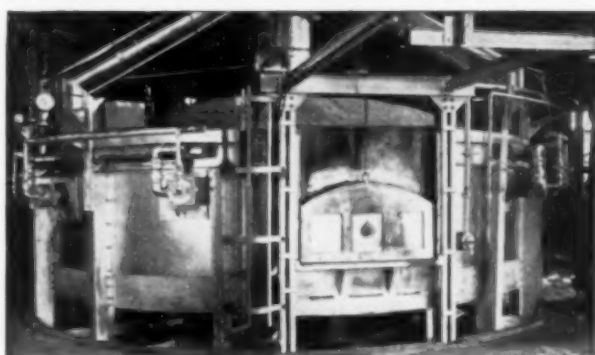
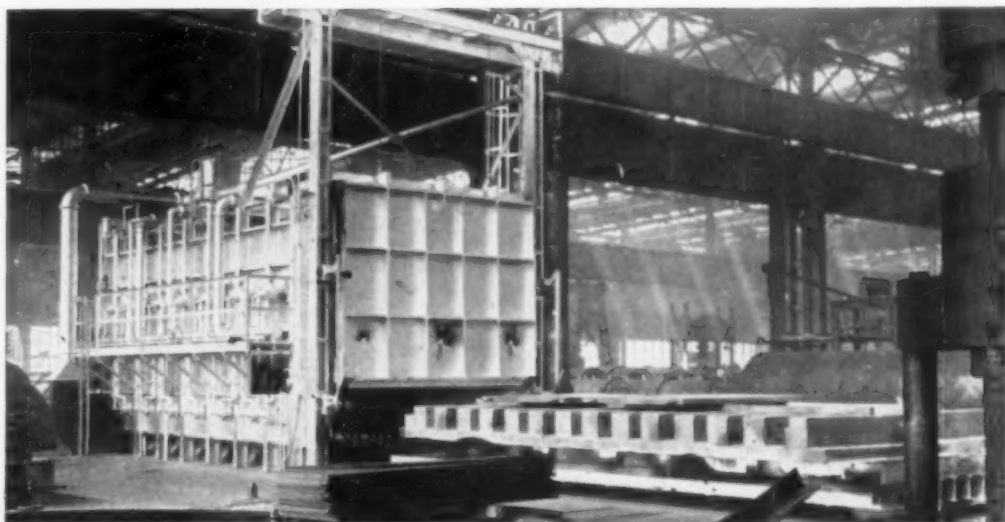
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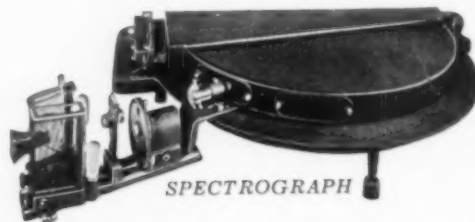
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SPECTROGRAPH

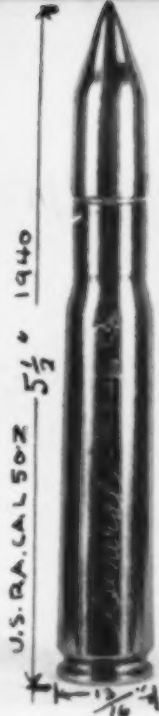
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HOLOCAUST

TONIGHT, from the overflowing morgues and crowded hospitals of Boston, hourly bulletins go on the air, listing the dead and dying, the maimed and missing in the greatest holocaust which seared the youth and hearts of Boston late last night when the Coconut Grove, a glided-fire-trap-joint with ersatz exits, burned trapping over seven hundred people. DEAD—438,—BURNED AND INJURED—231,—incomplete.

PANIC jammed revolving doors, fire exits were reported locked or missing. "Fireproof" paint didn't stop flames, did make gas to smother victims. With two hundred dead still unidentified every Saturday night stay-out, and every unlocated soldier, sailor or traveling salesman, is a suspected casualty. Hundreds of half-crazed families are tearing around in search of their own. So far, thank God, no G.A. people are on the lists.

AGRADE A enemy air raid could have caused far less casualties, and would probably have taught less men in uniform than this devastating fire. Adjectives, worn dog-eared by the mouths of drivell-dribblers on the radio, and chamber-maid journalism, seem, to this writer, inadequate to describe this disaster, possibly the world's worst in a single fire.

AS the hearses roll in Boston's streets, scurvy little politicians, whose negligence killed these people, will scurry like the rats they are to their brother rats who run other fire-trap py-joints. The smell of burning flesh and the shrieks ringing in their ears have, for the nonce, made them "Exit Conscious."

LOWELL POWELL, Chief Metallurgist of Warner Automotive Parts Co. (Div. of Borg-Warner Corp.), at Auburn, Ind., has written a comprehensive report on the "Smooth-Screw" furnace conveyor mechanism, built by General Alloys to H.H.H. Pat. Design, and installed Dec. 19, 1939, and still going strong. The "Smooth-Screw" Conveyor carries trays through a 40-ft. furnace singly, or in any number to a full load, at any desired speed. IT ELIMINATES THE DESTRUCTIVE COMPRESSION OF ALLOY TRAYS which occurs in all "Pusher" furnaces and is a vicious waste of alloy. In the "Smooth-Screw" design the furnace is self-emptying, no "dead" charge is necessary to push

CHIEF METALLURGIST OF INTERNATIONAL HARVESTER CORP'N

JOHN ROBINSON

JOHN ROBINSON, Chief Metallurgist of International Harvester Corporation, holds a unique position, in Peace and War. No organization of so many plants has so many operating Metallurgists and Heat Treat Executives knit so closely together for mutual co-operation. They quickly and effectively collect, disseminate and utilize vital information, new ideas, and improved methods and specifications.

ALL of this began years ago when much "Ferro-manureium" was confused with Metallurgy, when no Metallurgist could tell a real "He" blacksmithing Heat Treater about the fire and metal he lived with. In those days, you could always tell a Metallurgist but you couldn't tell him much.

Continued in next column

a live one out. The trays are used as CARRIERS, NOT RAMRODS. A copy of Mr. Powell's report will be sent you on request.

RECENTLY we bought, on the open market, some .50 cal. machine gun cartridges, with primers fired, converted to cigarette lighters with aluminum works and nice chrome plated dummy bullets. The base is inscribed "R.A. 1940 50 CAL Z". We wondered just whatinell Boy Scouts collecting scrap would think of cigar-store PRIORITIES on WAR materials. We gave these away, while the few lasted, at the National Metal Congress in Cleveland, got receipts for all of them. Many from W.P.B. and Army and Navy men asked "How Come?"

QUICKLY comes a letter from Major General L. H. Campbell, Jr., Chief of Ordnance. He had picked up the lighter trail two months sooner, found that the cartridge cases were made by Remington for the British Purchasing Commission and were rejected. They were sold by Remington in January 1941. In May 1941 Remington refused to sell more shells for lighters. "This is considered to be very foresighted on the part of the Remington Arms Company," writes General Campbell.

"TIM" Holden needs no introduction to A.S.M. "Spark-Plug" of the New York Chapter for years. "Tim" was Secretary when the Chapter was a pup and they can't lose him. Ahead of the parade as usual, Captain Holden is, he modestly states, "Serving in the East"—above.

HARVESTER has a long tradition of building hundreds of different types of overloaded and abused machines, built to work in dust and mud—winter in snow drifts.

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NO Lion Tamer had a thing on John Robinson when he was selected from a wide field and handed the job of co-ordinating the Metallurgy and Heat Treatment of all Harvester Plants, and establishing Central Control. John chose to "Sell" rather than tell. He weighed his men, their ideas, and his decisions. Weighed them so well, ruled so equitably that he soon earned the respect and affection of the entire organization, and the nickname "Judge."

JOHN ROBINSON, with the co-operation of his superiors and subordinates, worked through the years to streamline Harvester Heat-Treats, Processes and Metallurgy, and build up an organization from within. There is a deep loyalty in the Harvester Organization, whose wise Leadership has striven to first build MEN, then machines. That loyalty extends to their suppliers, particularly to men who, like myself, have had the pleasure and privilege of working with them on their smaller problems, growing up with them, watching the old timers climb the ladder, and the youngsters make their first rungs.

I'VE battled with John Robinson, pulled bulls and caught hell for it, and I've been thanked for jobs well done. Any time John wants my shirt he can have it, and so can his twenty odd "Boys", Head Men of Metals in I.H.C. plants who accompanied him to Cleveland, attending the Metal Congress with every hour scheduled, and an agenda covering problems to be studied for group discussion.

NO group at the Congress was so widely sought out for help in WAR PRODUCTION PROBLEMS as John Robinson's Gang—for Harvester has always shared knowledge. Looking younger and fitter than we've seen him in years, and tackling each new War Production job with increased vigor, John Robinson is helping to forge the largest and strongest link in the Harvester chain of AMERICAN TRADITION—VICTORY FOR ALLIED ARMS.


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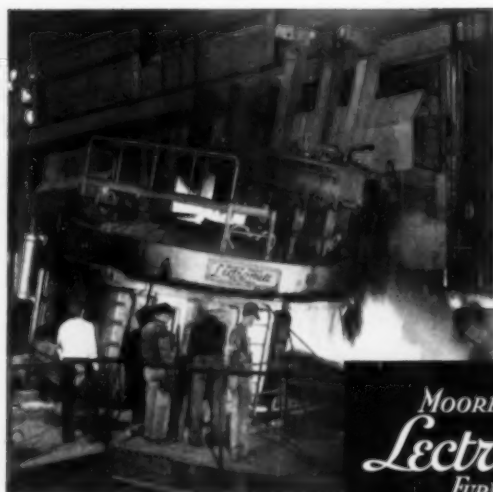
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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

METAL WORKING • FABRICATION

Kennametal tools, specifications and prices. McKenna Metals Co. Bulletin Hf-238.

140-page working manual on "Cylindrical Superfinishing." International Machine Tool Corp., Foster Div. Bulletin Hf-410.

Forging presses. Ajax Mfg. Co. Bulletin Ff-105.

Horizontal extrusion presses, rolling mills, pumps and accumulators. Hydropress, Inc. Bulletin Ff-394.

36-page pictorial story of the Ceco-stamp. Chambersburg Engineering Co. Bulletin Ff-132.

Cutting Oils. Cities Service Oil Co. Bulletin Ec-113.

Cutting Oil Handbook. D. A. Stuart Oil Co. Bulletin Ke-118.

Presses for Powder Metallurgy. F. J. Stokes Machine Co. Bulletin Af-335.

36-page booklet on properties and uses of cutting oils. Gulf Oil Corp. Bulletin Ef-360.

Guide book shows forty different ways to cut machining costs. Continental Machines, Inc. Bulletin Ef-170.

A new and attractively illustrated catalog describes the mounted wheels, Handee and Hi-Power tools and a wide variety of accessories developed by Chicago Wheel & Mfg. Co. Bulletin Kf-230.

Savings in oils, tool bits, grinding wheels. Sparkler Mfg. Co. Bulletin Kf-433.

New leaflet shows "dag" colloidal graphite as a lubricant for running-in internal combustion engines, compressors and other mechanical equipment. Acheson Colloids Corp. Bulletin Lf-465.

"Hyper-milling", a radical innovation in face-milling of steel, is described in booklet by Firth-Sterling Steel Co. Bulletin Lf-177.

Abrasive belt polishing machines. Divine Brothers Co. Bulletin Kf-434.

Metal cuttings saws. Wells Mfg. Co. Bulletin Kf-316.

Cutting oils. Warren Refining & Chemical Co. Bulletin Kf-454.

New 32-page book presents details, photographs and tables on operation of abrasive cutting machines. Andrew C. Campbell Div., American Chain & Cable Co. Bulletin Nf-466.

Convenient, pictorial chart shows abrasive cloth gadgets in a form that will guide users in the proper finishing operation. Behr-Manning Corp. Bulletin Nf-467.

FERROUS METALS

Enduro stainless steels. Republic Steel Corp. Bulletin Hf-8a.

Steel Stock List. Jos. T. Ryerson & Son, Inc. Bulletin Fe-106.

Hard Facing Alloys. Wall-Colmonoy Corp. Bulletin Hf-85.

Free Machining Steels. Monarch Steel Co. Bulletin Cd-255.

Tool Steels. Bethlehem Steel Co. Bulletin Ce-76.

Die Steels. Latrobe Electric Steel Co. Bulletin Ld-208.

Steel data. Vanadium-Alloys Steel Co. Bulletin Kd-294.

Enameling iron sheets. Inland Steel Co. Bulletin Ld-295.

NAX high tensile low alloy steels. Great Lakes Steel Corp. Bulletin Kd-229.

Loose-leaf reference book on molybdenum steels. Climax Molybdenum Co. Bulletin Hb-4.

Simplified method for calculating heat treatment of alloy steels. Peter A. Frasse & Co., Inc. Bulletin Cf-172.

Four Coppco tool steels. Copperweld Steel Co. Bulletin Cf-311.

Nitralloy and the Nitriding Process. Nitralloy Corp. Bulletin Df-116.

Information for determining overall heat transfer rates. International Nickel Co. Bulletin Kf-45.

Wall Chart on spark testing tool steels. Carpenter Steel Co. Bulletin Kf-12.

Aircraft steels, bearing steels. Rotary Electric Steel Co. Bulletin Kf-429.

Steels. Boker & Co. Bulletin Kf-450.

Cold drawn steels. Wyckoff Drawn Steel Co. Bulletin Kf-99.

Steel Data Sheets. Wheelock, Lovejoy & Co. Bulletin Ox-74.

Saving of stainless steel through use of Pluramelt. Allegheny Ludlum Steel Corp. Bulletin Df-92.

New 60-page data book on molybdenum wrought steels has been issued by Molybdenum Corp. of America. Bulletin Nf-312.

New leaflet describes Jessop Steel Co.'s Truform die steels. Bulletin Nf-173.

Shop notes on the machining of stainless steels are presented in new 24-page book by Rustless Iron & Steel Corp. Bulletin Nf-169.

NON-FERROUS METALS

Silver alloy brazing. Handy & Harman. Bulletin Hf-126.

Bronze. Frontier Bronze Corp. Bulletin Kf-455.

Various applications of bronze in the war industries are shown in new 8-page booklet by Ampco Metal, Inc. Bulletin Lf-175.

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Company Address

(Students—please write direct to manufacturers.)

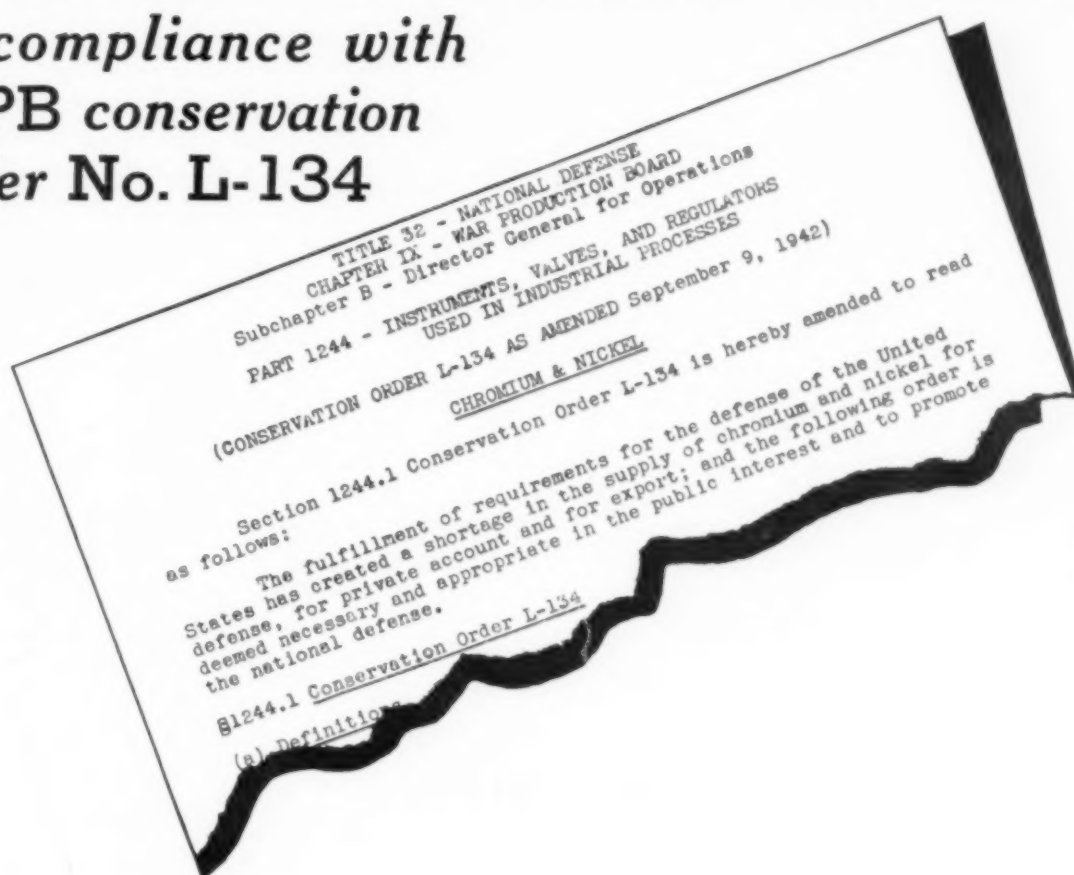
Check or circle the numbers referring to literature described on these four pages.

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Hf-238	Kf-434	Hb-4	Kd-89	Hf-69	Ne-330	Hf-49	Df-5	Ef-323	Lf-356	Ff-396	D-17
Hf-410	Kf-316	Cf-172	Lf-436	Gf-248	Cf-308	Lf-55	Bf-234	Ef-386	Lf-111	Hf-131	Bb-84
Ff-105	Kf-434	Cf-311	Lf-382	Kf-134	Df-377	Hf-419	Af-226	Kf-399	Hf-296	Bf-16	Ee-208a
Ff-394	Nf-466	Df-116	Af-337	Kf-425	Lf-7	Lf-203	Ne-114	Kf-388	Hf-68	Db-18	Cf-370
Ff-132	Nf-467	Kf-45	Kf-54	Lf-301	Lf-46	Lf-145	Be-30	Kf-439	Hf-189	Ka-13	Ef-327
Ec-113	Hf-8a	Kf-429	Kf-437	Af-331	Lf-462	Lf-287	Ce-219	Kf-444	Ne-329	Bf-124	Ef-387
Ke-118	Fe-106	Kf-450	Kf-421	Lf-461	Lf-67	Lf-44	Ff-11	Kf-446	Ff-397	Bf-357	Kf-422
Af-335	Cd-255	Ox-74	De-307	Lf-60	Lf-110	Lf-38	Nd-123	Kf-447	Ff-193	Af-195	Kf-423
Ef-360	Ce-76	Df-92	Ec-215	Nf-470	Ke-135	Lf-463	Hf-43	Kf-448	Ff-240	Ga-90	La-23
Ef-170	Ld-208	Nf-312	Df-371	Hf-401	Ef-21	Lf-443	Gd-2	He-41	Hd-29	Hd-271	Ge-152
Kf-230	Kd-294	Nf-160	Hf-415	Ff-320	Kf-206	Ff-286	Re-82	Ke-211	Bf-332	Kf-451	Ke-151
Kf-433	Ld-295	Kf-453	Gf-67	Ff-213	Kf-87	Bf-66	Ke-200	Nf-154	Df-376	Kf-438	Ka-174
Lf-463	Kd-229	Lf-175	Nf-239	Nv-259	Kf-428	Ce-302	Hb-81	Nf-305	Ef-381	Kf-430	Lf-299
Lf-177			Nf-163	He-6	Kf-458	Ff-321	Cf-70	Nf-141	Gf-256	Ce-269	Lf-108
			Ff-10	Bf-345	Kd-288	Bf-183	Df-60	Ce-75	Nb-212	Bf-233	Lf-460
			Ne-86	De-303	Ox-97	Lf-461	Cf-24	Ie-88	Ge-143	Ld-32	Lf-459
			Ff-393	Af-198	Ke-37	Na-138	Cf-367	Ld-57	Kf-426	Bf-165	Lf-459
			Ld-191	Cf-137	Nf-3	Ke-34	Ef-379	Ef-218	Kf-456	Af-237	Nf-468
			Ge-63	Hb-180	Hf-46	Lb-23	Ef-319	Df-100	Kf-457	Bf-339	Nf-469
						Ne-15	Df-300	Nf-192	Ne-234	He-184	

How to CONSERVE...

ESSENTIAL INSTRUMENT MATERIALS

*in compliance with
WPB conservation
order No. L-134*



Many valuable solutions to problems arising from the new WPB Conservation Order L-134, which drastically limits the use of various materials for thermocouples, lead wire, thermometer bulbs, protecting tubes, etc., are given in the recently published Wheelco Supplement to Thermocouple Bulletin S2-3. The Supplement S2-3 is the result of an extensive analysis of the WPB Order L-134 by Wheelco Engineers and is published for the benefit of those who will be affected by this order. The Supplement also contains a partial summary of the L-134 Order; the complete L-134 Order as amended September 9, 1942, additions and revisions applying to various items in the Wheelco S2-3 Bulletin and a complete list of Wheelco Sales and Service Engineers who can help you with your instrument problems.

Write for your FREE copy of Supplement to Bulletin S2-3 and the issue of Wheelco Comments which deals with Thermocouple construction and maintenance.

Also request copy of Bulletin S2-3 if you do not have a copy.

Wheelco Instruments Co.

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Originator of "Electronic Principle" Temperature Controls

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Copper Alloys. American Brass Co. Bulletin Kd-89.

Aluminum alloys for aircraft. Reynolds Metals Co. Bulletin Lf-436.

October Copper & Brass Research Assn. "Bulletin" features article on radio's use of brass. Bulletin Lf-382.

Platinum Metal Catalysts. Baker & Co., Inc. Bulletin Af-337.

New edition of "Machining Alcoa Aluminum". Aluminum Co. of America. Bulletin Kf-54.

New, complete catalog describes features and savings incorporated in die casting equipment of Lester-Phoenix, Inc. Bulletin Kf-437.

Cerrosafe, a low temperature melting metal, used to accurately proof-cast cavities. Cerro de Pasco Copper Corp. Bulletin Kf-421.

Aluminum Castings. National Bronze & Aluminum Foundry Co. Bulletin De-307.

Dowmetal data book. Dow Chemical Co. Bulletin Ec-215.

Handy, compact reference data on brass and bronze castings. Hammond Brass Works. Bulletin Df-371.

Reference on properties of lead. St. Joseph Lead Co. Bulletin If-415.

Catalog of brass, bronze and iron alloys. Cramp Brass and Iron Foundries Div., Baldwin Locomotive Works. Bulletin Gf-67.

New "Copper Guide" is a handbook for easy reference to technology and properties of copper and copper base alloys, welding technique, etc. Revere Copper and Brass, Inc. Bulletin Nf-239.

80-page Duronze Manual, well indexed for reference, presents data on high strength silicon bronzes. Bridgeport Brass Co. Bulletin Nf-163.

WELDING

Arc Welding. Lincoln Electric Co. Bulletin Ff-10.

Welding Stainless. Page Steel & Wire Div., American Chain & Cable Co., Inc. Bulletin Ne-86.

New chart explains how to select proper flux for every welding, brazing and soldering job, gives answers to 400 metal-joining questions. Krembs & Co. Bulletin Ff-393.

Electrode quantity and welding time graph. Arcos Corp. Bulletin Ld-191.

Oxy-acetylene welding and cutting. Linde Air Products Co. Bulletin Ge-63.

"Fight-waste" booklet. Air Reduction Sales Co. Bulletin If-69.

Shield Arc electrodes. McKay Co. Bulletin Gf-248.

A-C welders for use with Union-melt process. Westinghouse Electric & Mfg. Co. Bulletin Kf-134.

Sciaky radial portable welder. Sciaky Brothers. Bulletin Kf-425.

Castolin Eutectic Alloys as a substitute for scarce bronze or brass welding rods. Eutectic Welding Alloys Co. Bulletin Lf-301.

Two-stage "Regulator" for producing a non-fluctuating welding flame. National Cylinder Gas Co. Bulletin Af-331.

New catalog contains 88 pictures of new Suttonizing welding method for reclamation of high speed steel tools. Welding Equipment and Supply Co. Bulletin Lf-464.

Arc welding accessories available through General Electric Co. are illustrated in new Bulletin Lf-60.

New precision welder with the streamlined arc is described in leaflet issued by Hercules Electric & Mfg. Co., Inc. Bulletin Nf-470.

TESTING & CONTROL

"Kodak Products for Industrial Radiography". Eastman Kodak Co. Bulletin Ff-395.

Inspection of non-magnetic metals with the new Zyglon method. Magnaflux Corp. Bulletin If-401.

Industrial radiography with radium. Canadian Radium & Uranium Corp. Bulletin Ff-320.

Metallurgical laboratory apparatus. Burrell Technical Supply Co. Bulletin Ff-213.

Tension and compression strains. American Instrument Co. Bulletin Nv-259.

X-Ray Diffraction Unit. General Electric X-ray Corp. Bulletin Hc-6.

Radium for industrial radiography. Radium Chemical Co., Inc. Bulletin Bf-345.

Modern Polishing. Tracy C. Jarrett. Bulletin De-303.

Film and plate processing equipment for spectro analysis. Harry W. Dietert Co. Bulletin Af-198.

Optical Aids. Bausch & Lomb Optical Co. Bulletin Ce-35.

Universal testing machines and typical uses. Riehle Testing Machine Div., American Machine and Metals, Inc. Bulletin Cf-157.

Pyrometer Controller. Illinois Testing Laboratories, Inc. Bulletin Hb-180.

Universal enclosed terminal head. Arklay S. Richards Co. Bulletin Ne-330.

Metallographic polishing powder. Conrad Wolff. Bulletin Cf-368.

Portable Brinell hardness tester and folding Brinell microscope. Andrew King. Bulletin Df-377.

8-page leaflet makes a detailed presentation of the Coleman universal spectrophotometer. Wilkens-Anderson Co. Bulletin Lf-7.

Revised catalog of Micromax thermocouple pyrometers has just been issued by Leeds & Northrup Co. Bulletin Lf-46.

Laboratory and industrial electric furnaces manufactured by Cooley Electric Mfg. Corp. are described in new Bulletin Lf-462.

Automatic stress-strain recording is discussed comprehensively and equipment is pictured in new booklet by Baldwin-Southwark Div., Baldwin Locomotive Works. Bulletin Lf-67.

New bulletin interprets WPB conservation order L-134 as it applies to use of thermocouples and thermocouple protecting tubes for pyrometric instruments. Wheelco Instruments Co. Bulletin Lf-110.

Metallurgical Equipment. Adolph I. Buehler. Bulletin Ke-135.

Hardness testing equipment. Wilson Mechanical Instrument Co., Inc. Bulletin Cf-22.

Potentiometer temperature indicators. Foxboro Co. Bulletin Ef-21.

Gage blocks, comparators, projectors. George Scherr Co. Bulletin Kf-206.

Pyrovac radiation pyrometer. Bristol Co. Bulletin Kf-87.

Complete information on National Spark Testing Assn.'s methods of ascertaining the chemical composition of steel. Bulletin Kf-428.

Slomin high speed electrolytic analyzers and other metallurgical laboratory equipment. E. H. Sargent & Co. Bulletin Kf-458.

Surface Analyzer. Brush Development Company. Bulletin Kd-288.

Polishing Machine. Cincinnati Electrical Tool Co. Bulletin Ox-97.

Micro-Optical Pyrometers. Pyrometer Instrument Co. Bulletin Ke-37.

X-Ray metallurgical laboratory service is described and illustrated in new file folder issued by Claud S. Gordon Co. Bulletin Nf-52.

64-page booklet on the precision control of industrial processes has been issued by Brown Instrument Co. Bulletin Nf-3.

HEATING • HEAT TREATMENT

Tempering, annealing, stress-relieving. Leeds & Northrup Co. Bulletin Hf-46.

Use Handy Coupon on Page 1106 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 1106, 1110 and 1112.



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Ten years of steel progress in one of America's most modern and coordinated mills guarantees the quality of steels going into thousands of bearings used in war-time equipment.

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

56-page vest pocket data book on heat treating practices and procedures. Chicago Flexible Shaft Co. Bulletin Hf-49.

24-page catalog describes gas, oil and electric Holden heat treating pot furnaces, and baths. A. F. Holden Co. Bulletin Lf-55.

Industrial furnaces for ingots, billets, slabs, bars, rods and gun barrels. Wellman Engineering Co. Bulletin If-419.

New 8-page booklet describes and illustrates gas, oil and electric heat treating and carburizing furnaces of Holcroft & Co. Bulletin Lf-203.

Faster production with Tocco hardening, brazing, annealing and heating machines is set forth in new 16-page booklet by Ohio Crankshaft Co. Bulletin Lf-145.

Kleen-well oil strainers for quench oil cooling systems is described in leaflet by Bell & Gossett Co. Bulletin Lf-287.

Gas cracking unit for production of a protective atmosphere during heat treatment of alloy and high carbon tool steels is described by Hevi-Duty Electric Co. in new Bulletin Lf-44.

Liquid salt baths for carburizing, annealing, reheating, tempering and neutral hardening are described by E. F. Houghton & Co. in new Bulletin Lf-38.

Annealing and stress-relieving of cartridge cases are discussed by Surface Combustion Corp. in new Bulletin Lf-51.

Unichrome alkaline copper processes for improvement of selective hardening and deep drawing of steel are described by United Chromium, Inc., in new Bulletin Lf-463.

Method of handling cylinder anhydrous ammonia for metal treaters is comprehensively described and pictured in 12-page booklet by Armour Ammonia Works, division of Armour and Co. Bulletin Lf-443.

"Pulverized Coal, the Victory Fuel". Amsler-Morton Co. Bulletin Ff-286.

Heat treating furnaces. Johnston Mfg. Co. Bulletin Ff-155.

Heat treating production. Lindberg Engineering Co. Bulletin Bf-66.

Rotary Hearth Furnaces. Lee Wilson Sales Corp. Bulletin Ce-302.

Industrial furnaces, equipment for bright annealing stainless steels and ammonia dissociation equipment. Drever Co. Bulletin Ff-321.

Industrial ovens, rod bakers, welding rod ovens, furnaces. Carl-Mayer Corp. Bulletin Bf-183.

Modern electric furnaces for heat treating are described by Harold E. Trent Co. in new Bulletin Lf-461.

Low pressure oil burners. North American Mfg. Co. Bulletin Na-138.

Industrial Furnaces. W. S. Rockwell Co. Bulletin Ke-34.

Non-metallic Electric Heating Elements. Globar Div., Carborundum Co. Bulletin Lb-25.

Certain Curtain Furnaces. C. I. Hayes, Inc. Bulletin Ne-15.

Modern Shell Furnaces. Mahr Manufacturing Co. Bulletin Bf-5.

Butterfly Valves. R-S Products Corp. Bulletin Bf-234.

Gas-fired Forge Furnaces. Eclipse Fuel Engineering Co. Bulletin Af-226.

Vertical Furnace. Sentry Co. Bulletin Ne-114.

Conveyor Furnaces. Electric Furnace Co. Bulletin Be-30.

Industrial Carburetors. C. M. Kemp Mfg. Co. Bulletin Ce-219.

Condensed Catalog. American Gas Furnace Co. Bulletin Ff-11.

Convected Air Furnace. Despatch Oven Co. Bulletin Nd-123.

Molten Salt Baths. E. I. DuPont de Nemours & Co., Inc., Electrochemicals Department. Bulletin If-413.

Heat treatment in electric salt bath furnaces. Ajax Electric Co., Inc. Bulletin If-43.

New Electric Furnace. American Electric Furnace Co. Bulletin Gd-2.

Furnace Experience. Flinn & Dreflein Co. Bulletin Be-82.

Dehumidifier. Pittsburgh Electro-dryer Corp. Bulletin Bb-187.

Furnaces. Dempsey Industrial Furnace Corp. Bulletin Ke-260.

High Temperature Fans. Michiana Products Corp. Bulletin Hb-81.

Turbo-compressors. Spencer Turbine Co. Bulletin Cf-70.

Drycolene. General Electric furnace atmosphere. Bulletin Df-60.

Electric Furnaces for laboratory and production heat treatment. Hoskins Manufacturing Co. Bulletin Cf-24.

Control of temperatures of quenching baths. Niagara Blower Co. Bulletin Cf-367.

Electric box type and muffle furnaces. H. O. Swoboda, Inc. Bulletin Ef-379.

Lithco, the chemically-neutral heat treating process, and Lithcarb, the process for fast, bright gas-carburizing. Lithium Corp. Bulletin Ef-319.

Dual-Action quenching oil. Gulf Oil Co. Bulletin Df-360.

Induction heating. Induction Heating Corp. Bulletin Ef-323.

Internally heated salt bath furnaces and pots. Upton Electric Furnace Div. Bulletin Ef-386.

Sub-zero equipment for aluminum storage, shrinking of metal parts. Kold-Hold Mfg. Co. Bulletin Kf-399.

S.F.E. Standard Industrial furnace catalog. Standard Fuel Engineering Co. Bulletin Kf-388.

Controlled atmosphere furnace for heat treatment of tool and alloy steels. Delaware Tool Steel Corp. Bulletin Kf-439.

Low temperature equipment for aging, shrinking, etc. Deepfreeze Div., Motor Products Corp. Bulletin Kf-444.

Heat treating furnaces. McCann Furnace Co. Bulletin Kf-446.

Furnaces. Tate-Jones Co. Bulletin Kf-447.

Gas-burning equipment. National Machine Works. Bulletin Fe-310.

Furnaces. Vulcan Corp. Bulletin Kf-448.

Electric Furnaces. Ajax Electro-thermic Corp. Bulletin He-41.

New Heat Source, for Heat Treating, Brazing and Melting of ferrous and non-ferrous metals. Lepel High Frequency Laboratories, Inc. Bulletin Ke-211.

16-page engineering and data booklet on proportioning oil burners. Hauck Mfg. Co. Bulletin Nf-181.

8-page pictorial bulletin describes the heat treating service of Continental Industrial Engineers, Inc. Bulletin Nf-154.

Flame-type mouth and taper annealing machine for steel cartridge cases is described in new leaflet by Morrison Engineering Corp. Bulletin Nf-305.

No-Carb, a liquid paint for prevention of carburization or decarburization, is described and use illustrated in new leaflet by Park Chemical Co. Bulletin Nf-141.

REFRACTORIES & INSULATION

Insulating firebrick. Babcock & Wilcox Co. Bulletin Ce-75.

Heavy Duty Refractories. Norton Co. Bulletin Ie-88.

Super Refractories catalog. Carborundum Co. Bulletin Ld-57.

P. B. Sillimanite refractories. Chas. Taylor Sons Co. Bulletin Ef-218.

Conductivity and heat transfer charts. Johns-Manville. Bulletin Df-100.

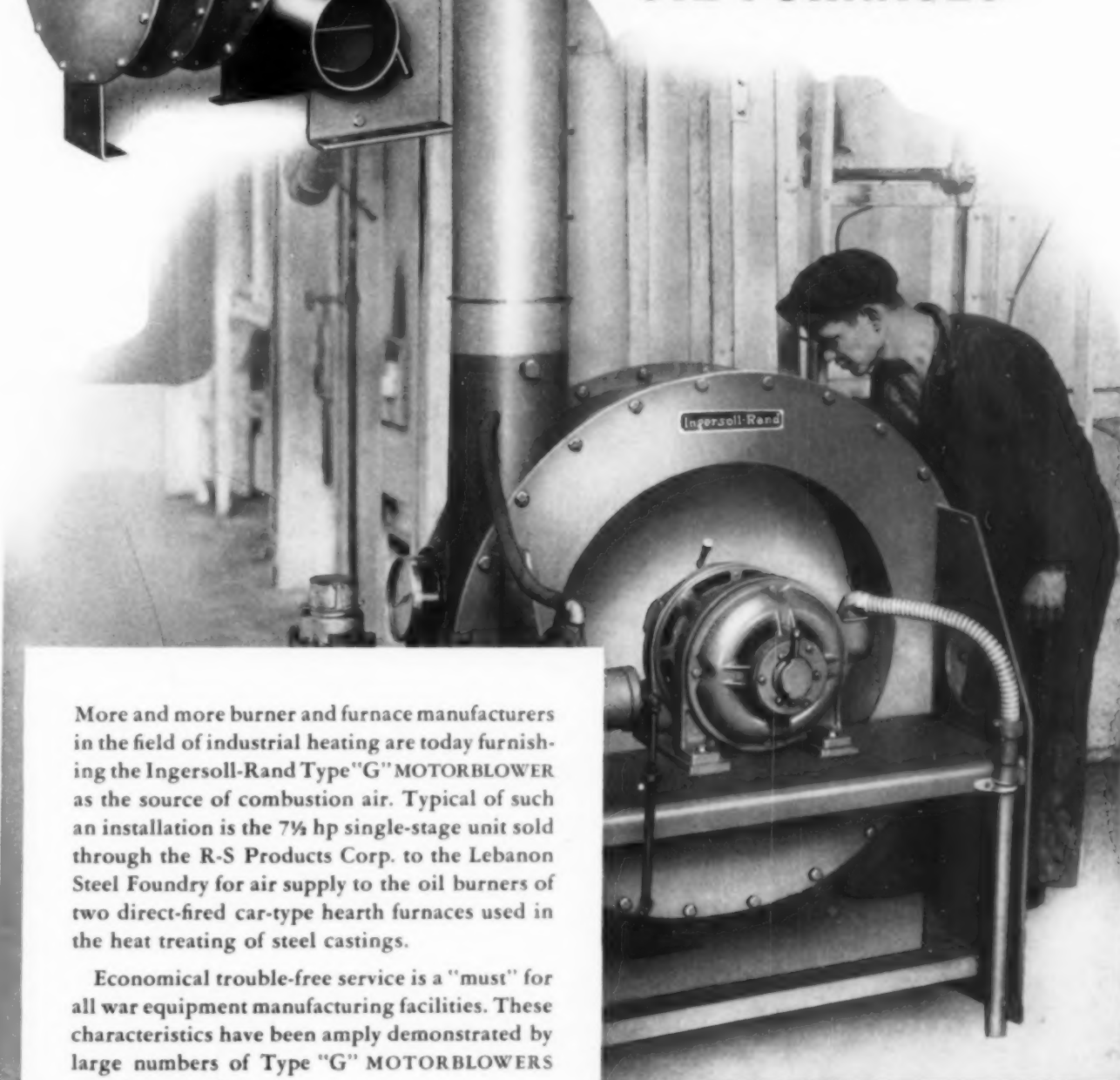
Savings in construction time, labor and money with use of the all Ramix bottom for basic open hearth furnaces are shown in new leaflet by Basic Refractories, Inc. Bulletin Nf-192.

Use Handy Coupon on Page 1106 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 1106, 1108 and 1112.

Type "G" MOTOR BLOWERS

with

R-S Products Corp. OIL FURNACES



More and more burner and furnace manufacturers in the field of industrial heating are today furnishing the Ingersoll-Rand Type "G" MOTOR BLOWER as the source of combustion air. Typical of such an installation is the 7½ hp single-stage unit sold through the R-S Products Corp. to the Lebanon Steel Foundry for air supply to the oil burners of two direct-fired car-type hearth furnaces used in the heat treating of steel castings.

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VOLUME: 100 to 4500 cfm. BULLETIN: Form 2671-B.

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Chicago	London	Melbourne	Mexico	Montreal	Rio de Janeiro
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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

FINISHING, PLATING, CLEANING

Technical and engineering data on Tygon and typical uses, such as tank linings, are presented by United States Stoneware Co. in new Bulletin Lf-356.

Detrex metal cleaning machines, metal cleaning chemicals and processing equipment are attractively described in new 24-page catalog by Detroit Rex Products Co. Bulletin Lf-111.

Cleaning Manual. Oakite Products, Inc. Bulletin Hf-296.

Airless Rotoblast. Pangborn Corp. Bulletin Hf-68.

A protective, deep black finish to steel. Heatbath Corp. Bulletin Hf-189.

Alvey Ferguson Co. shows how various product washing problems were solved. Bulletin Ne-329.

112-page manual "Chemicals by Glyco". Glyco Products Co., Inc. Bulletin Ff-397.

Pickling. Wm. M. Parkin Co. Bulletin Ff-193.

Modern Pickling. The Enthone Co. Bulletin Ff-240.

Cadmium Plating. E. I. duPont de Nemours & Co., Inc. Bulletin Hd-29.

Motor-Generators for electroplating and other electrolytic processes. Columbia Electric Mfg. Co. Bulletin Bf-352.

"Indium and Indium Plating". Indium Corp. of America. Bulletin Df-376.

Casting cleaning methods in foundries. N. Ransohoff, Inc. Bulletin Ef-381.

Jetal process and its characteristics as a protective coating. Alrose Chemical Co. Bulletin Gf-256.

Rust Preventative. Alox Corp. Bulletin Nb-212.

Electrochemical Descaling. Bullard-Dunn Process Div., Bullard Co. Bulletin Ge-143.

Comprehensive new booklet describes the rust inhibiting wax coatings for protection of metal against rust and corrosion developed by S. C. Johnson & Son, Inc. Bulletin Kf-426.

Tumbling and cleaning. Globe Stamping and Machine Co. Bulletin Kf-456.

Anodizing and plating equipment. Lasalco, Inc. Bulletin Kf-457.

Degreasers. Phillips Manufacturing Co. Bulletin Ne-254.

MELTING • CASTING • MILL OPERATIONS

Care of crucibles for brass, copper, aluminum and magnesium industries. Electro Refractories and Alloys Corp. Bulletin Ff-396.

Rotary positive blower installations in several fields, including smelting, steel mill and foundry. Roots-Connorsville Blower Corp. Bulletin Hf-131.

"Electromet Products and Service". Electro Metallurgical Co. Bulletin Bf-16.

Lectromelt Furnaces. Pittsburgh Lectromelt Furnace Corp. Bulletin Db-18.

Ingot Production. Gathmann Engineering Co. Bulletin Ka-13.

Operating Features, capacities, charging methods of the Heroult electric furnace. American Bridge Co. Bulletin Bf-124.

How Research Has Produced developments that make the side-blow converter process desirable as a source of high temperature metal. Whiting Corp. Bulletin Bf-357.

Fisher Furnace Co.'s stationary and tilting type crucible melting furnaces for ferrous and non-ferrous metals. Bulletin Af-195.

Manganese-Titanium Steels. Titanium Alloy Mfg. Co. Bulletin Ga-90.

Electric Furnaces. Detroit Electric Furnace Div., Kuhlman Electric Co. Bulletin Hd-271.

Chrom-X for steel mill and foundry. Chromium Mining & Smelting Co. Bulletin Kf-451.

Electric melting furnaces. Swindell-Dressler Corp. Bulletin Kf-438.

ENGINEERING • APPLICATIONS • PARTS

Electrical, corrosion and heat resisting alloys in rod, wire, ribbon and strip forms. Wilbur B. Driver Co. Bulletin Kf-430.

Carburizing Boxes. Pressed Steel Co. Bulletin Ce-269.

Duraspun Centrifugal Castings. Duraloy Co. Bulletin Bf-233.

X-Ray Inspected Castings. Electro Alloys Co. Bulletin Ld-32.

Meehanite Castings. Meehanite Research Institute. Bulletin Bf-165.

Ledaloyl, self-lubricating bearings. Johnson Bronze Co. Bulletin Af-237.

Metal Baskets. W. S. Tyler Co. Bulletin Bf-359.

Steel Castings. Chicago Steel Foundry Co. Bulletin He-184.

Heat Resisting Alloys. General Alloys Co. Bulletin D-17.

Pipes and Tubes. Michigan Steel Casting Co. Bulletin Bb-84.

Metal Powders. Metals Disintegrating Co. Bulletin Ec-208a.

Bimetals and Electrical Contacts. The H. A. Wilson Company. Bulletin Cf-370.

Handy wire data chart. Callite Tungsten Corp. Bulletin Ef-327.

Corrosion and heat resistant alloy. Lebanon Steel Foundry. Bulletin Ef-387.

Lead-base metals. Magnolia Metal Co. Bulletin Kf-422.

Comprehensive, pictorial description of wide range of applications where Velvetouch Bimetallic friction material may be installed is described in new plastic-bound booklet by the S. K. Wellman Co. Bulletin Kf-423.

Cr-Ni-Mo Steels. A. Finkl & Sons Co. Bulletin La-23.

Duriron. A new bulletin on steam jets, ejectors, tank outlets and spray nozzles. Duriron Co. Bulletin Ge-152.

Heat and corrosion-resisting castings. Standard Alloys Co., Inc. Bulletin Ke-151.

Centrifugal Iron. Shenango-Penn Mold Co. Bulletin Ka-174.

Industrial baskets, crates, trays and fixtures are described by Rolock, Inc., in new Bulletin Lf-299.

Standard and special shapes of seamless steel tubing are described and pictured in new leaflet by Summerill Tubing Co. Bulletin Lf-108.

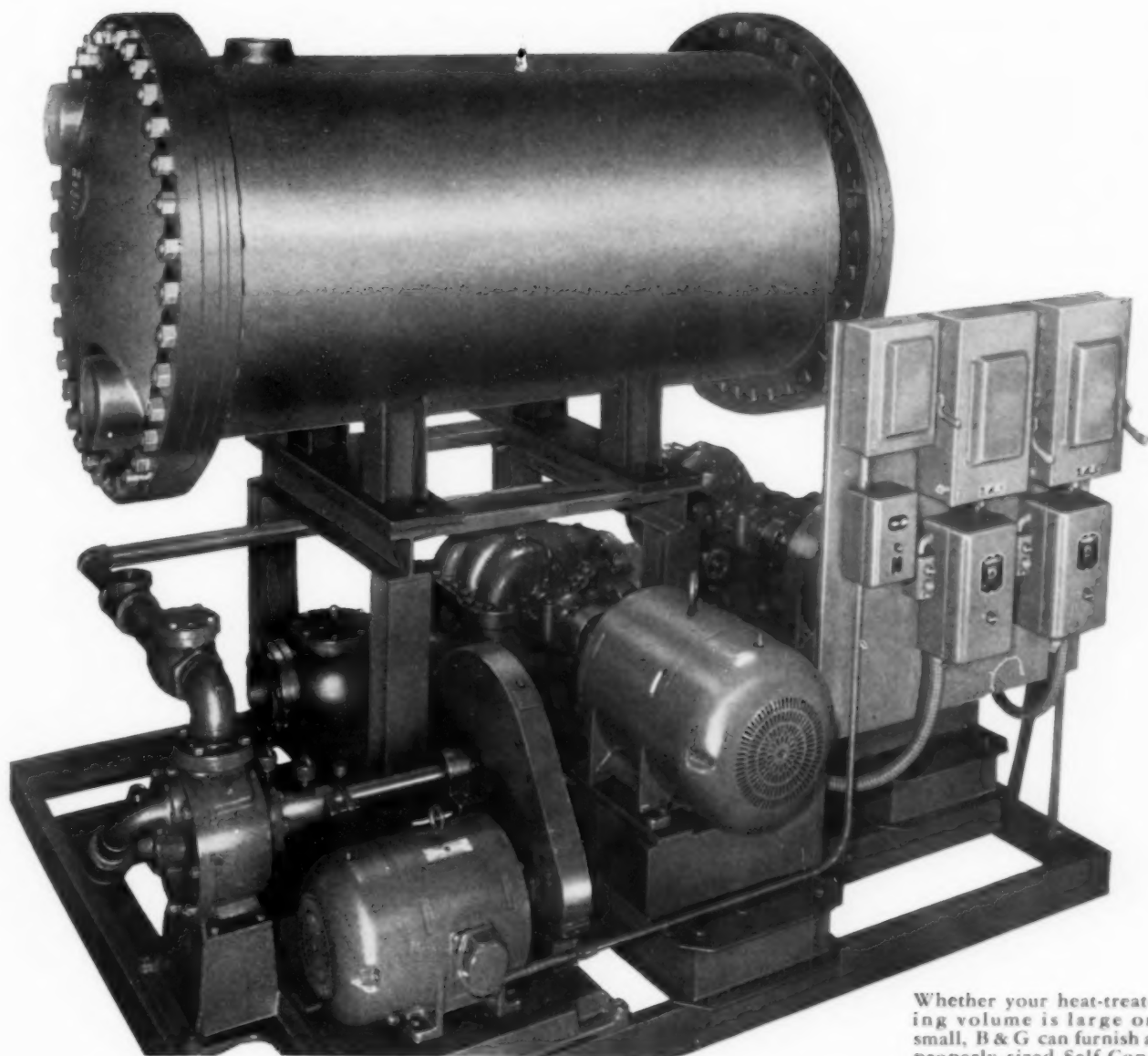
New 12-page booklet describes background, manufacture and typical applications of Tungsten. Cleveland Tungsten, Inc. Bulletin Lf-460.

Handling baskets for heat treating, washing, dipping, degreasing, etc., are shown in new leaflets issued by Union Steel Products Co. Bulletin Lf-459.

Instrument Specialties Co. has issued "Better Brush Springs", reference leaflet showing how "Micro-processed" beryllium copper brush springs have answered demands and includes data and formulae for spring design. Bulletin Nf-468.

Conversion from several types of scarce metals to malleable iron is described and illustrated in new booklet by Lake City Malleable Co. Bulletin Nf-469.

Use Handy Coupon on Page 1106 for Ordering Helpful Literature. Other Manufacturers' Literature Listed on Pages 1106, 1108 and 1110.



Whether your heat-treating volume is large or small, B & G can furnish a properly sized Self-Contained Oil Cooler Unit.



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BELL & GOSSETT CO., MORTON GROVE, ILLINOIS

December, 1942; Page 1117

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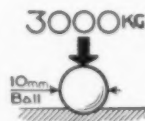
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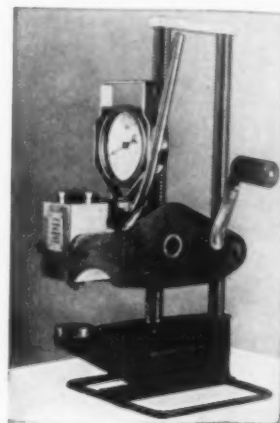
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THERMOCOUPLE WIRES
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CONNECTORS
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PRODUCTION, development and improvement of quality in heavy duty forgings, die blocks and hot work steels. You can bank on every product that carries the FINKL name.

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STATES
WAR
BONDS
AND
STAMPS



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ELECTRIC
FURNACE
FUSED

BETTER "eyes" FOR FURNACES...

with better sighting tubes for INDUSTRY

Costly, special alloy sighting tubes to observe and control temperatures in billet heating furnaces frequently had to be replaced owing to oxidation and scaling. Our engineers working with Leeds & Northrup Co. recommended tubes of *Crystolon* (Norton trade-mark for silicon carbide). These *Crystolon* tubes have been preeminently successful.

Crystolon tubes together with delicate measuring instruments are helping industry meet the rigid requirements of war-time production.

Norton engineers work with the most refractory commercial substances known: *Crystolon* (SiC), *Alundum* (fused Al_2O_3) and fused Magnesia grains. They are constantly developing better refractory mixes to meet the needs of war-time industry.

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Worcester

Massachusetts



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TESTED BY TIME

Proved by Experience

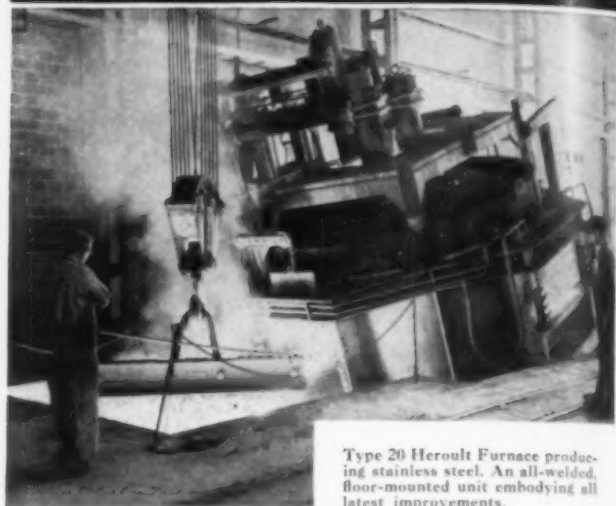
Eclipse Seamless Pressed Steel Heat Treating Containers are the Ideal Heat Treating Containers

Write for Bulletin N-10

Eclipse Fuel Engineering Company
ROCKFORD ILLINOIS

McKee Eclipse

Heroult ELECTRIC FURNACES



Type 20 Heroult Furnace producing stainless steel. An all-welded, floor-mounted unit embodying all latest improvements.

PARTICULARLY designed and equipped for high-quality melting and refining of ferrous materials by either basic or acid process—including alloy, tool and forging steels, iron and steel castings. Any capacity from ½ ton to 100 tons; removable roof, chute, machine or hand charging.

AMERICAN BRIDGE COMPANY

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Columbia Steel Company, San Francisco, Pacific Coast Distributors
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UNITED STATES STEEL

THERMOSTATIC BI-METALS

ELECTRICAL CONTACTS

Percolators or Pursuit Planes

★ Almost overnight, whole industries have changed over from peacetime to war production. ★ Yet, whether it's brooders or bombers, transformers or transports, percolators or pursuit planes, the need for Wilco specialized thermostatic bi-metals and electrical contacts remains unchanged. Resistance bi-metals (from 24 to 440 ohms, per sq. mil, ft.) and high and low temperature thermostatic bi-metals are available in wide variety. ★ Also Wilco electrical contact alloys (in Silver, Platinum, Gold, Tungsten, Metal Powder Groups).



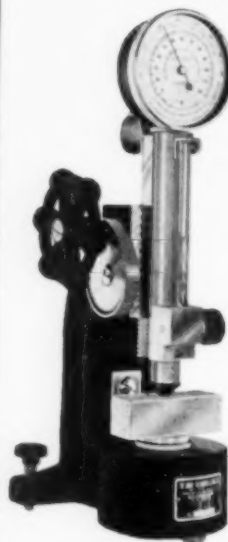
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105 CHESTNUT ST., NEWARK, N. J.

Branches: Chicago and Detroit

HARDNESS TESTING

Brinell - Shore - Scale



Included in our improved Portable Scleroscope Model D-1. This efficient single scale tester registers Brinell-Shore values without damage to the work. The old standby during the First World War is ready to serve again.

Write for circular.

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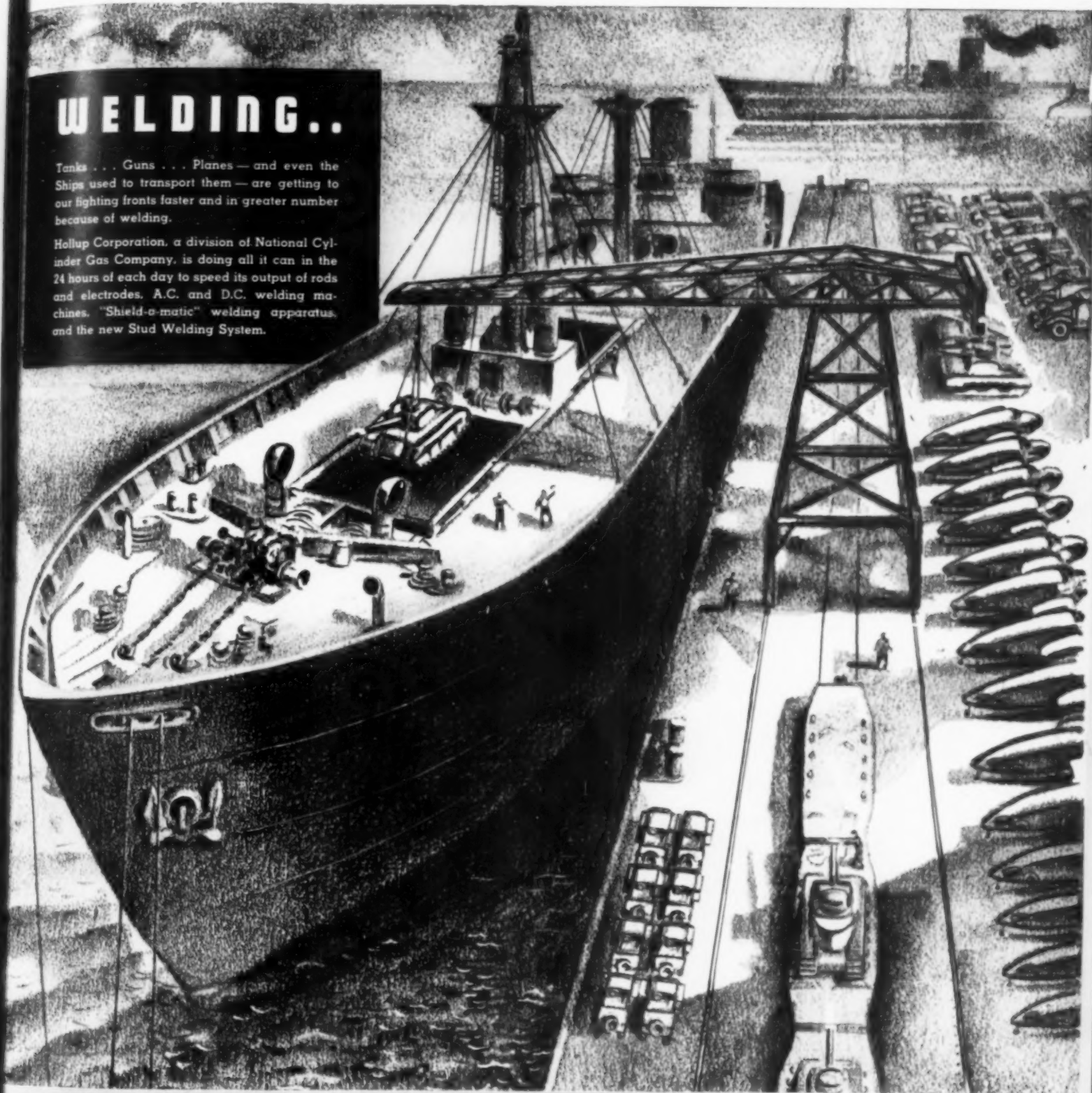
9025 Van Wyck Ave.

JAMAICA, N. Y.

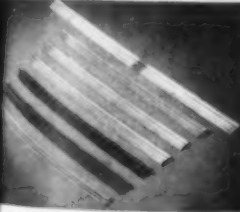
WELDING..

Tanks . . . Guns . . . Planes — and even the Ships used to transport them — are getting to our fighting fronts faster and in greater number because of welding.

Hollup Corporation, a division of National Cylinder Gas Company, is doing all it can in the 24 hours of each day to speed its output of rods and electrodes, A.C. and D.C. welding machines, "Shield-o-matic" welding apparatus, and the new Stud Welding System.



HOLLUP products and services are helping speed war production



"Shield-o-matic" protected arc electrodes in many types and sizes, for the best results for any job.



Electric welders for A.C. or D.C. operation are available in a complete range of sizes to meet any requirement.



"Shield-o-matic"—fully automatic shielded-arc welding process which meets all code requirements.



Stud welding system for production end-welding of steel sections to metal surfaces.

HOLLUP products may help speed your output . . . Write for literature, specifying equipment in which you are interested.



HOLLUP CORPORATION
DIVISION OF
NATIONAL CYLINDER GAS COMPANY

205 W. WACKER DRIVE

Offices in Principal Cities

CHICAGO, ILLINOIS

ELECTRODE MANUFACTURING PLANTS—CHICAGO, ILL. STOCKTON, CAL. AND TORONTO, CANADA



Check Into This!

THE IDEAL FURNACE FOR ALUMINUM AND MAGNESIUM DIE CASTING

Wide-flange drip ring to eliminate metal splash into furnace during dipping.

McKee Zero Governor to provide accurate gas regulation.

McKee "HE" Burner to provide high input with wide range of turndown.



Non warping top casting with expansion ring.

Refractory lined combustion chamber with insulation enclosed in steel shell.

Heavy bottom casting to provide rigid support.

SUPPLIED IN 150 TO 675 LB. CAPACITY FOR MELT DOWN OR HOLDING

Air Draw Furnaces

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Forge Furnaces

Rivet Heaters

Pot Furnaces for Oil, Lead & Salt

Bell Furnaces

Soft Metal Furnaces

Eclipse Fuel Engineering Company
ROCKFORD ILLINOIS

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MAKE YOUR OWN CUTTING TOOLS *with the new* **COLMONOY WCR ALLOYS**

Bridge the gap between high speed steel and the carbides. Reclaim old, and make new cutting tools by welding. The process is simple. To fabricate a typical tool —

1. Undercut carbon steel shank, leaving a fillet for ease in welding.
2. Fill undercut, using ordinary hard facing welding procedure.
3. Hot wipe, to approximate shape, to save grinding.
4. Wet grind, using green silicon carbide rough and finish wheels.

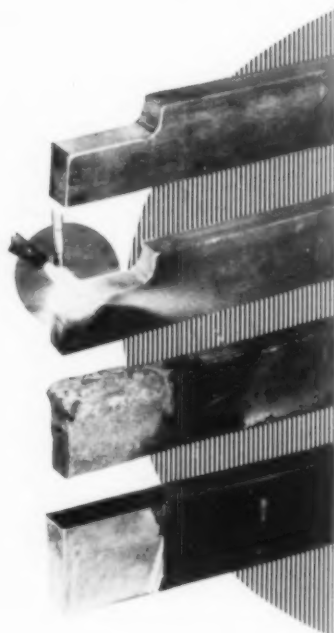
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Immediate delivery of all grades of WCR Alloys at all branches.

WALL-COLMONOY CORP.

720 Fisher Bldg., Detroit, Mich.

Branches in New York City, Blasdell, N. Y., Chicago, Tulsa, Los Angeles, and in Canada.



MISCO HIGH TEMPERATURE ALLOY SHEET WALL CARBURIZING BOXES

*Conserve
Nickel and
Chromium*



MISCO
Heat and Corrosion Resistant Alloys

Furnace Parts -
Roller Rails -
Chain - Trays -
Retorts -
Conveyor Rolls -
Carburizing and
Annealing Boxes -
Dipping Baskets -
Cyanide and
Lead Pots -
Centrifugal Castings

MISCO sheet carburizing boxes are at least 50% lighter than cast boxes of equal capacity.

Their construction is planned for most efficient service.

Thermal stresses are reduced and pound for pound they last longer. They heat rapidly, save fuel, and reduce handling time. Based on our experience with thousands of carburizing boxes of all types, they afford maximum service per dollar of investment, and provide the greatest output in a given period of time.

Michigan Steel Casting Company

MISCO
Heat and Corrosion Resistant Alloys

One of the World's Pioneer Producers of Heat and Corrosion Resistant Alloy Castings

1980 GUOIN STREET · DETROIT · MICHIGAN

December, 1942; Page 1129

GRAINAL

Over 300,000 tons of GRAINAL-Treated
steels now in the hands of consumers

Leading steel makers now finishing many
thousands of tons a month — Rate
rapidly rising

Over 3 Years of large-scale commercial
use in transmission gears, axles, shafts,
spindles and other dynamically stressed
parts

for Increasing the Hardening Capacity of Steel

Effects of a High Order

The effect of GRAINAL on hardening capacity is of a sufficiently high order that along with its other merits, GRAINAL may relieve the pressure on many other steel hardening elements which, due to emergency conditions, are in the critical class.

At the same time, GRAINAL makes possible in many steels favorable combinations of engineering properties that cannot be secured by conventional practices. For example, in full hardened steels, GRAINAL produces new and better balances between usually incompatible properties—hardness versus toughness, strength versus impact resistance. In fabrication, GRAINAL-treated steels generally behave better than other steels of the same hardening capacity.

Grainal Simple to Add

GRAINAL treatment is the irreducible minimum in simplicity—a small amount of alloy added after the usual finishing practice.

Assures Uniformity of Product

The composition of GRAINAL is "balanced" so that under normal steel making practice, no element can be added in harmful quantities. Greater uniformity of product is thereby assured.

GRAINAL is entirely a "plus value"—a new way to develop unusual properties in quenched and tempered carbon and low-alloy steels.



MULTIPLE UNIT LABORATORY FURNACES

ELECTRIC EXCLUSIVELY

The seven examples of Multiple Unit Laboratory heat treating equipment shown have been used extensively for thirty years, providing types for all laboratory furnace and hot plate requirements. Each type of Multiple Unit equipment has the exclusive feature of a multiple number of heating units, each readily replaceable by the user. This results in economy and uninterrupted operation.



**Multiple Unit Muffle
Furnace**

4 standard sizes, used with detached rheostat — for drying precipitates — ash determinations — ignitions—heat treating, etc. up to 1850° F. (1010° C.)



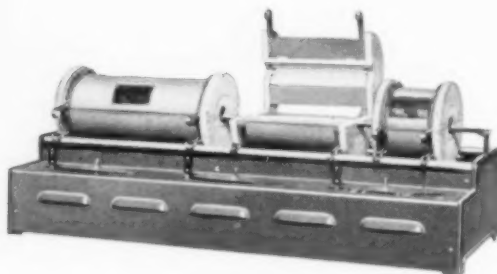
**Multiple Unit Solid Com-
bustion Tube Furnace**

10 standard sizes—for carbon determinations and special heat treating operations up to 1950° F. (1065° C.)



**Multiple Unit Crucible
Furnace**

5 standard sizes—for melting small quantities of metals — pyrometer calibration — molten salts and heating all materials, when contained in crucibles, up to 1950° F. (1065° C.)



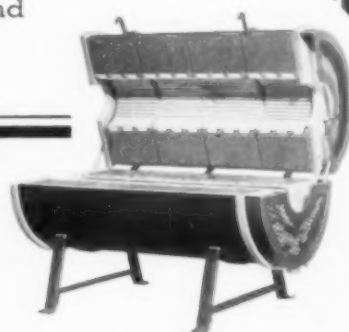
**Multiple Unit Organic Combustion
Furnace**

Sections four, eight, and twelve inches long —each with separate rheostat control—operations up to 1832° F. (1000° C.)—an outstanding achievement for accuracy and comfort in operation.



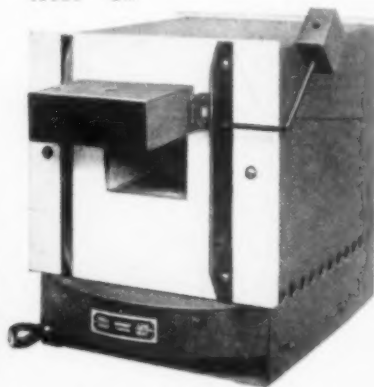
Multiple Unit Hot Plate

7 standard sizes—each with three heats—for evaporating solutions — drying precipitates—distilling, boiling, etc. Maximum temperature 750° F. (400° C.)



**Multiple Unit Hinged
Combustion Tube
Furnace**

10 standard sizes—for carbon determinations—special organic analyses and special heat treating applications up to 1950° F. (1065° C.)



**Multiple Unit Muffle
Furnace**

3 standard sizes with built-in rheostat — same uses and temperatures as the other described muffle furnace.

HEVI DUTY ELECTRIC COMPANY

LABORATORY FURNACES

MULTIPLE UNIT

ELECTRIC EXCLUSIVELY

MILWAUKEE, WISCONSIN

Columbia TOOL STEEL

MEETING DEMANDS—

Maximum production of the implements of war depends on users of tool steels.

Columbia is all-out for its users with all the facilities, skill and ingenuity at its command.

Ask for help if you need it.

*It pays to use
Good Tool Steel.*

COLUMBIA TOOL STEEL COMPANY

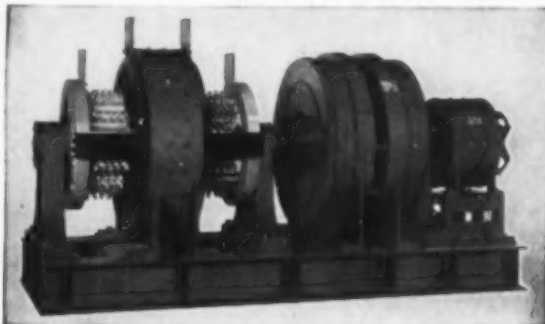
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GENERAL OFFICE AND WORKS

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COLUMBIA MOTOR-GENERATORS

for Electro-Plating and
other Electrolytic Processes



Columbia generators embody every feature essential to dependable, 24-hour operation. They are built for electroplating service in sizes of 6 to 20 volts, 500 to 20,000 amperes, for anodic treatment of aluminum in sizes of 40, 50 and 60 volts, 500 to 3,000 amperes. Columbia generators for other electrolytic processes range from $\frac{1}{2}$ to 250 KW, 100 to 40,000 amperes, 6 to 60 volts.

Prompt shipment can be made on any type and size. What are your requirements?

COLUMBIA ELECTRIC MFG. CO.

4519 Hamilton Ave.

Cleveland, Ohio

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**BRASS AND BRONZE
CASTINGS up to 5400 lbs.**

MODERN melting, moulding, core room, sand handling and sand control equipment, enable a trained personnel to produce the finest quality castings. Copper Base Alloys, Aluminum Bronze, Manganese Bronze and PMG metal (Copper, silicon, iron alloy), produced to all Federal, Navy and Ordnance, as well as individual specifications. Strict adherence to chemical and physical specifications.



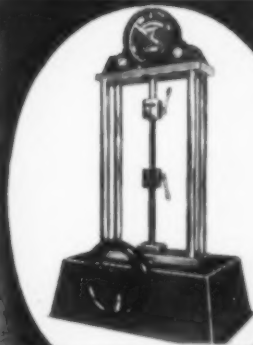
• Spindle Raising Columns for Gun Mounts. Navy Specification 49-B-3e; weight of rough castings, each 96 pounds.

Write for new book—"Practical Data on Brass and Bronze Castings"

HAMMOND BRASS WORKS

Hammond, Indiana

Dillon TENSILE TESTER



PORTABLE 10,000 POUNDS CAPACITY

Weight: 83 pounds, height: 22 inches—yet allowing all type stress tests up to 10,000 pounds! Large specimen space, for wide range of materials. Extremely accurate, easy to operate, low in cost.

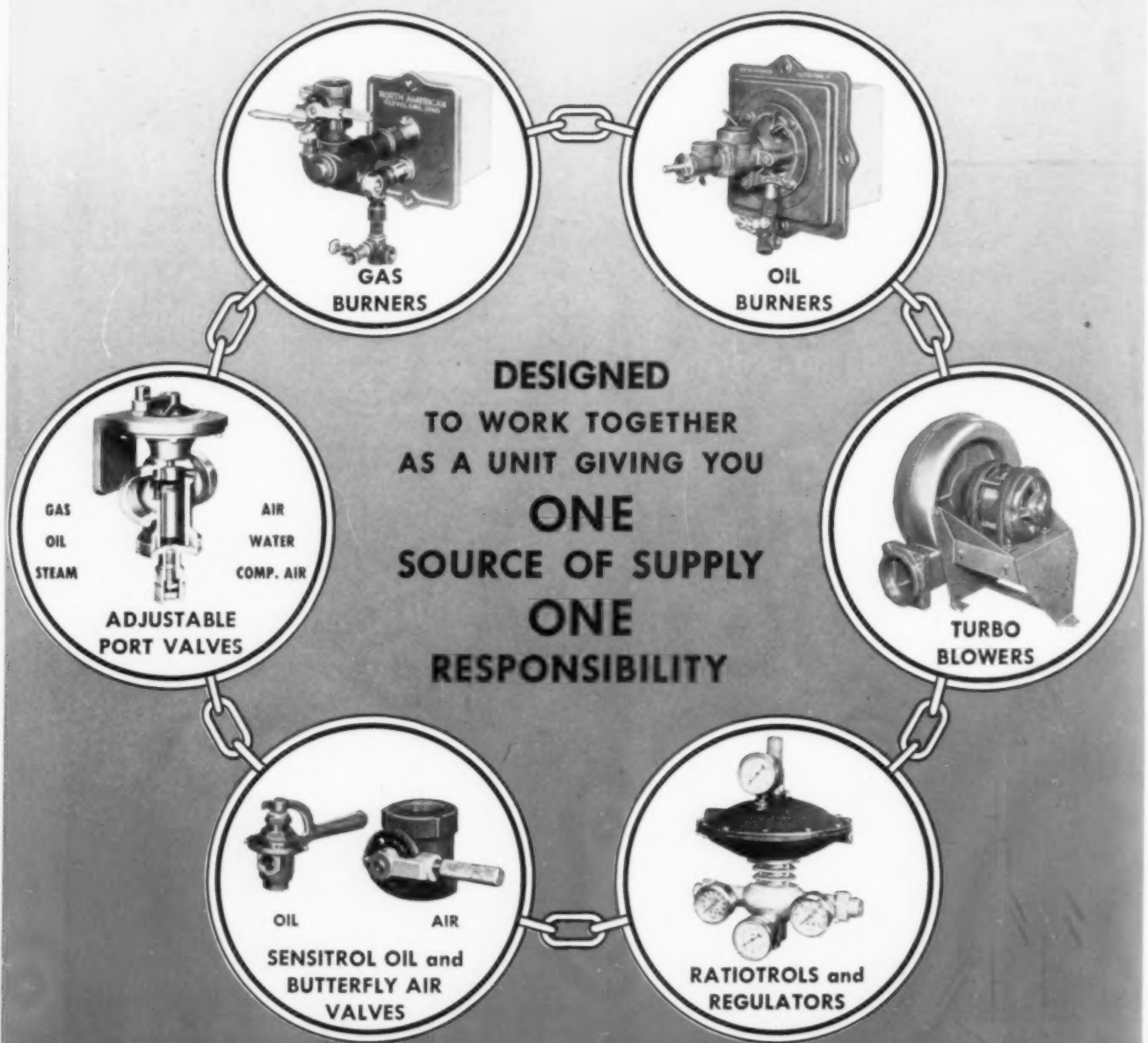
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NORTH AMERICAN COMBUSTION EQUIPMENT

Will save fuel for your country and your company!



Why not consult a North American representative?

THE NORTH AMERICAN MANUFACTURING COMPANY

MANUFACTURERS OF INDUSTRIAL FUEL BURNING EQUIPMENT FOR GAS OR OIL
BRANCH OFFICES with FIELD ENGINEERS in PRINCIPAL CITIES

CLEVELAND, OHIO

...the *VICTORY* team!



WAR BONDS

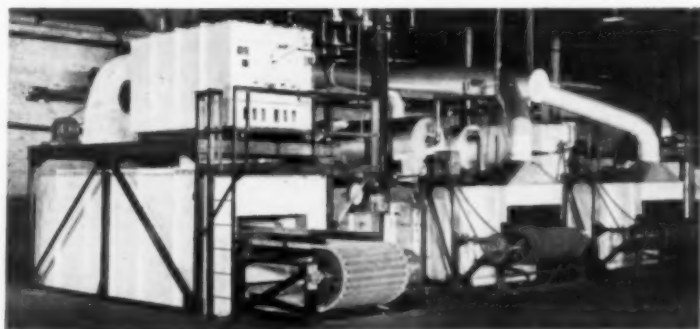
GREATER PRODUCTION

*I*N MANY plants, the problem of meeting war production schedules has been solved only to bring up another, that of reaching a still higher quota so urgently needed to give our armed forces the equipment they must have for all-out offensive.

Improved equipment is the answer! For instance, you'll get *Better, Faster, Cheaper* production when you install the latest design of furnaces and ovens created by Carl-Mayer.

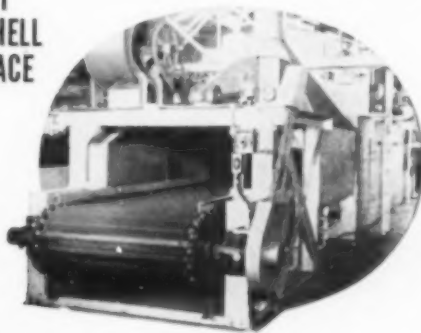
Wire for a Carl-Mayer Engineer, or write for Bulletin 241.

OVER 20 YEARS' EXPERIENCE



Battery of High and Low Temperature Recirculating Type Furnaces

**SHOT
AND SHELL
FURNACE**



This Carl-Mayer Shell Furnace is built for stress relieving shot and shells from 20 to 105 mm. Many repeat orders from outstanding plants.

THE CARL-MAYER CORP.
3030 Euclid Ave. Cleveland, Ohio

**AIR DRAW FURNACES, SHELL FURNACES, BATCH TYPE FURNACES,
ROD BAKERS, WELDING ROD OVENS, CORE AND MOLD OVENS**

American Magnesium Corp.
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Steel Castings

CUT ASSEMBLY AND FINISHING COSTS . . . AND GIVE YOU LIGHTER, STRONGER, MORE ACCURATE WAR PRODUCTS

There is only one way to build products for war. That is to give them the strength, hardness, rigidity, resistance to fatigue and stresses, and resistance to heat, cold and pressure which specifications demand. Such specifications are best served by STEEL CASTINGS.

Nor is that all. Metallurgical Engineers and designers are finding that STEEL CASTINGS cost less . . . that they require less time to handle and machine . . . that they make possible the application of weight and strength just where it is most needed.

STEEL CASTINGS require less time to prepare for manufacture . . . and at the same time give you ALL of the desirable qualities of steel . . . often the only kind of casting which will meet specifications.

Better get the facts, today! Get in touch with the foundry near you (their location is starred on the map) and find out how STEEL CASTINGS fit your production needs . . . and what is more important how they can profitably help you maintain schedules.

THESE ELEVEN STARRED PLANTS . . . IF YOU ARE IN THEIR AREA . . . CAN ECONOMICALLY IMPROVE YOUR

WAR-TIME PRODUCTS



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Steel Casting Division
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4



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PRODUCTS WHICH SAVE
WITH STEEL CASTINGS**

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Automotive
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Bridge
Chemical & Paint Works
Compressors (Pneumatic)
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Crushing Machinery & Cement
Mill
Dredge
Electrical Machinery &
Equipment
Elevator
Engine
Food Processing & Packing
Plant
Foundry Machinery &
Equipment
Gas Producer & Coke Oven
Gears
Heat Treating Furnace &
Equipment
Hoist & Derrick
Iron & Steel Industries
Metallurgical Machinery
Mining Machinery & Equipment
Oil or Gas Field & Refinery
Ordnance
Overhead Crane & Charging
Machine
Paper Mill
Printing Press
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11



FOR AIRCRAFT STAINLESS STEEL

Many manufacturers and users of aircraft stainless steel report better workability and fabrication with lower initial cost when TAM Low-Carbon Ferro-Titanium is used as a carbide stabilizer. In a recent article, a competent authority in the steel industry states—"Today we must budget our time and capabilities to the best interests of the complete defense program... some of the stabilized stainless alloys are fundamentally less expensive than others and it has not been possible to discern substantial differences in corrosion resistance, stability, or workability... certain customers say Titanium alloy works much better in their fabricating processes." Write for data and recommended uses of Titanium for aircraft stainless steel.

TITANIUM
ALLOY MANUFACTURING COMPANY

GENERAL OFFICES AND WORKS: NIAGARA FALLS, N. Y., U. S. A.
EXECUTIVE OFFICES: 111 BROADWAY, NEW YORK CITY

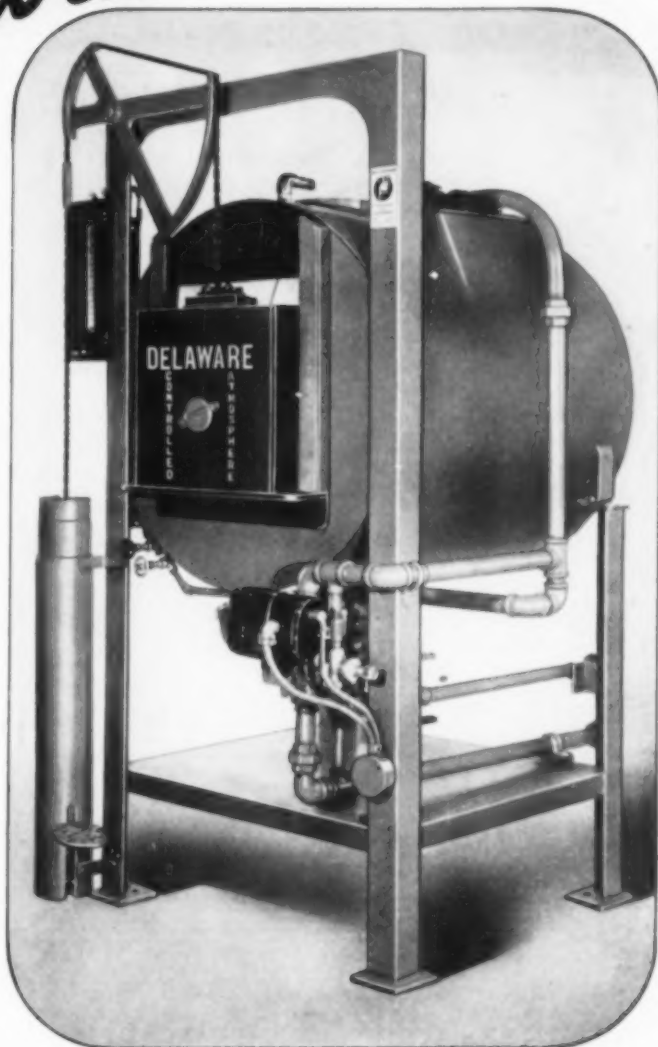
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17

Superior Features

IN A DELAWARE CONTROLLED ATMOSPHERE FURNACE

1. Uniformity of hearth and thermo-couple temperature.
2. Uniformity of temperature throughout the entire muffle.
3. Uniformity of temperature throughout the work area of the hearth.
4. Short time coming to temperature.
5. Fully automatic, straight line temperature control — permitting exact temperature control indefinitely.
6. Quiet operation.
7. Perfect insulation.
8. Low upkeep cost and fuel economy.
9. Door operation, foot pedal *and* hand control.
10. Designed for consistent operation at all temperatures up to 2500° F.
11. Low labor cost, because automatic temperature control permits operator to give all his attention to loading, timing, and quenching.
12. Front baffle tiles seal heat within the muffle and give flexibility in operating when door is raised or lowered.
13. Bridged hearth tiles carry all the load stresses—quickly removed for repairs.
14. "Pilot light" method of firing muffle atmosphere excess gases at combustion chamber vents.
15. Designed for low or high pressure artificial, natural, or propane gas—without changing burner equipment.
16. Correct atmospheres for steels quenched up to 1700° F. without muffle gas addition.
17. Simplified atmosphere control for hardening above 1700° F. including High Carbon-High Chrome and Molybdenum High Speed steels.



If your work involves the heat-treatment of tool and alloy steels—from the simplest straight carbon type on through the various moly high speed steels—you will be interested in the DELAWARE CONTROLLED ATMOSPHERE FURNACE. Representing a development of many years of heat-treating experience, it embodies patented features which make it the most perfect heat-treating tool of its kind.

DELAWARE

TOOL STEEL CORPORATION

WILMINGTON • DELAWARE

December, 1942; Page 1147

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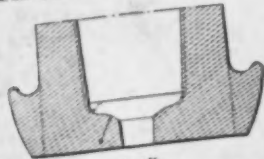
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Figure 85
Bottom nanotube designed to control dendritic structure and volume
but crop Gethmann patent No. 2,882,702

A further advantage of this type chamber bottom is the lengthened mold life. One of the difficulties of previous designs of concavo-convex mold bottoms is that because the lower or convex walls are tangent to the walls of the plug recess, there is a hump or protruberance extending around and just above the mold bottom opening. This around and just above the mold bottom opening. This hump is particularly vulnerable to the cutting action of the hot liquid steel as it spins laterally from the closure

STEEL PRODUCTION

within the bottom opening, resulting in premature erosion of the chamber bottom and consequently in shortened mold life. The bottom shown in Figure 56 eliminates as far as possible this localized and premature erosion or cutting away of the mold wall surrounding the bottom opening and reduces by as much as 9°, the amount of crop necessary to get rid of the undergrowth of the metal at the bottom end of the ingot.



Figure 57
Banded corners on the right bottom
to center. Banded. Corners
about 1/2" x 1/2"

A further saving thru reduced butt crop is obtained in big-end-up mill ingots by raising the corners of the ingot as shown in Figure 57. These raised corners permit reduction of the ingot in the mill with a minimum of fish-tailing, saving as much as 2% on large ingots.

In order to protect the bottom of the mold against the erosive action of the flowing stream, plates are frequently employed. When they are, they should be attached to the plug by means of a pin or they may float up into the

More than 4% butt crop is too much!

THE lower third of a big-end-up ingot from a properly deoxidized and carefully teemed heat is the soundest and most nearly homogeneous part. For this reason, it's important in today's production of armament steels that butt discard be kept to the minimum.

With correct mold design, the amount of butt crop need not exceed 2% to 4%, the exact amount depending on the size and shape of the ingot.

The length and proportions of the radii describing the mold chamber bottom determine the size and shape of the cone formed in the ingot due to the interference of the dendritic crystals that grow up from the bottom with those that grow in from the sides. There is almost always some porosity



near the apex of this cone and the butt crop must be sufficient to clear this up, but in the average mill size ingot, not more than 2% of the ingot volume need be affected by the cone and its accompanying porosity.

By raising the corners of such an ingot (see illustration), fishtailing can be practically eliminated.

The designing of molds for minimum butt
crop is only one of the subjects treated in
the new edition of *The Ingot Phase of
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